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OF

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PREFACE

THIS book has been written in response to the requests of many teachers in order to supply in separate form, but amplified and enlarged, those portions of *A Rational Geography* which deal with the subject in its practical aspect. It contains three sections entitled respectively (i) Climate, (ii) The World as a Globe, and (iii) Maps and Map-Making. The first two of these have been adapted from the preliminary chapters of Parts i and ii of *A Rational Geography*, but they have been expanded and re-arranged, and a number of new exercises have been added. Part iii is to all intents and purposes new.

The book is thus entirely distinct from and independent of *A Rational Geography*, which includes only a sufficient amount of matter on the practical side to enable the pupil to grasp the method of that particular book.

The *Practical Geography* as a whole or in part is suitable for the higher forms of Elementary Schools as well as for Secondary Schools. The Revision Exercises at the end of chapters have been taken in most cases from questions set for the Universities' Local or the Civil Service Examinations.

The term "Practical Geography" may be held to cover a geography, but it is here used in the more limited se as including chiefly those portions of the subject that be studied with the help of instruments. The authors hav endeavoured to keep in mind the limited time availabl for this kind of work in most schools and not to include more than can reasonably be expected to be done as part of the usual "four years' course."

E. Y.
J. F.

APPARATUS FOR THE PRACTICAL TEACHING OF GEOGRAPHY

The attention of Teachers is directed to the List of Apparatus on pp. 161-2, which includes the various instruments, etc., required for the practical work given in this book. All the articles are prepared with a special view to the requirements of schools, being strongly made and sold at the lowest price compatible with good workmanship and proper accuracy.

PRICES will be sent on application.

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PART I

CLIMATE

CHAPTER I

CLIMATE—TEMPERATURE—THERMOMETERS—TEMPERATURE CHARTS

One of the commonest words to be met with in an account of any country is the word **climate**. One may say, perhaps, that, as far as the inhabitants of any country are concerned, the climate of that country is one of its most important features. By the climate of a place we mean the average character of the weather. If we wish to find out how the climate of a country is to be described, we must take account of the temperature of the air at different seasons of the year, we must note the direction and force of the winds, we must measure the amount of rain that falls annually.

It is possible, and advisable, to make a practical study of the climate of your own district. The observations that have to be made require to be continued over a long period of time. They will teach you how information relating to the weather is collected, and you will finally be better able to understand, not merely the descriptions given in books, of the climate of your own and other countries, but also the conditions which cause the climate of one country to differ from that of another country.

Temperature.—The first and easiest observations to be made are upon the temperature of the air. We say that a summer day is hotter than a day in winter, or that the temperature is higher in summer than in winter. As the countries in the south of Europe are warmer than those in the north of Europe, we say that the temperature of southern Europe is higher than that of northern Europe.

Whenever we talk about the temperature of a place, we really compare its temperature with that of some other place. Suppose that we could suddenly bring a man from the south of Greece, and another from the extreme north of Russia, and put them both in London on the same day. The man from Greece would find England a cold place, and, comparing it with Greece, would say that its temperature was low. But the man from the north of Russia would find England a warm place, and, comparing it with Russia, would say that its temperature was high.

It is at once evident that a person's feelings are no real guide to the temperature of a place. In fact it is quite a common thing to hear two people differ about the temperature at the same place and at the same moment, one declaring it to be cold, and the other declaring it to be warm. We therefore need an instrument to tell us what the real temperature is, for, as we have seen, we cannot depend on our own sensations. The instrument used is called a **thermometer.**

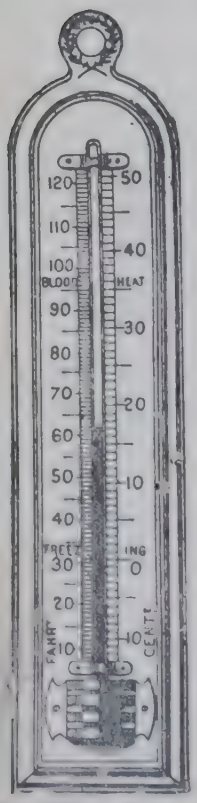


FIG. 1.
THERMOMETER.

Thermometers.—Exercise 1.—Examine an ordinary thermometer. It consists of a narrow stem and a wider bulb (Fig. 1). In the bulb and in a part of the stem there is a liquid. Sometimes this liquid is alcohol, in which case it is coloured red. Sometimes the liquid is mercury. On the thermometer itself, or on the frame which supports it, there are a number of marks and figures forming a **scale.**

Two scales are in common use in this country. One is called the Fahrenheit scale, and the other is called the Centigrade scale. In England we use the Fahrenheit thermometer for domestic purposes and the Centigrade thermometer for scientific work. On the Continent of Europe most countries employ the Centigrade thermometer both for domestic and scientific purposes.

Exercise 2.—**The Fahrenheit Thermometer.**—Place a Fahrenheit thermometer in a beaker of ice and water. To what number on the scale does the liquid in the ther-

mometer fall? This is called the **freezing-point.** Write down in your notebook:

"The freezing-point on a Fahrenheit thermometer is marked . . ."

Now place the same thermometer in the steam from boiling water. To what point does the liquid in the thermometer rise? This is called the **boiling-point.** Write down in your notebook:

"The boiling-point on a Fahrenheit thermometer is marked . . ."

The space between the two points is divided into degrees. Write down in your notebook.

"On a Fahrenheit thermometer there are . . . degrees between the boiling and the freezing-points."

Exercise 3.—The Centigrade Thermometer.—Repeat the above experiments, using a Centigrade thermometer. Write down the results of your observations in the manner given for the Fahrenheit thermometer. You will see that whenever we talk of the temperature at any place as being so many degrees, we must state with what kind of a thermometer the observations were made.

Exercise 4.—Temperature Charts.—During the month of November, 1906, a thermometer at Stockholm was read every morning at 8 o'clock.

The readings were as follows:

Nov.	1	42° F.	Nov.	16	39° F.
„	2	43° F.	„	17	36° F.
„	3	41° F.	„	18	32° F.
„	4	41° F.	„	19	34° F.
„	5	41° F.	„	20	36° F.
„	6	41° F.	„	21	42° F.
„	7	42° F.	„	22	35° F.
„	8	42° F.	„	23	48° F.
„	9	41° F.	„	24	49° F.
„	10	32° F.	„	25	47° F.
„	11	30° F.	„	26	38° F.
„	12	32° F.	„	27	35° F.
„	13	35° F.	„	28	29° F.
„	14	37° F.	„	29	38° F.
„	15	38° F.	„	30	33° F.

We can represent these results in the following way (Fig. 2). On a piece of squared paper, draw two lines at

right angles. On the horizontal line write 1, 2, 3, 4, 5, etc., referring to the days of the month. On the vertical line write as shown, 20, 25, 30, 35, referring to the readings of the thermometer. Now on the first of November, the thermometer at Stockholm, at 8 o'clock in the morning, stood at 42° F. On the vertical line numbered 1, mark the point 42. On November 2, the thermometer stood at 43° F. On the line 2 mark the point 43. In this way a series of

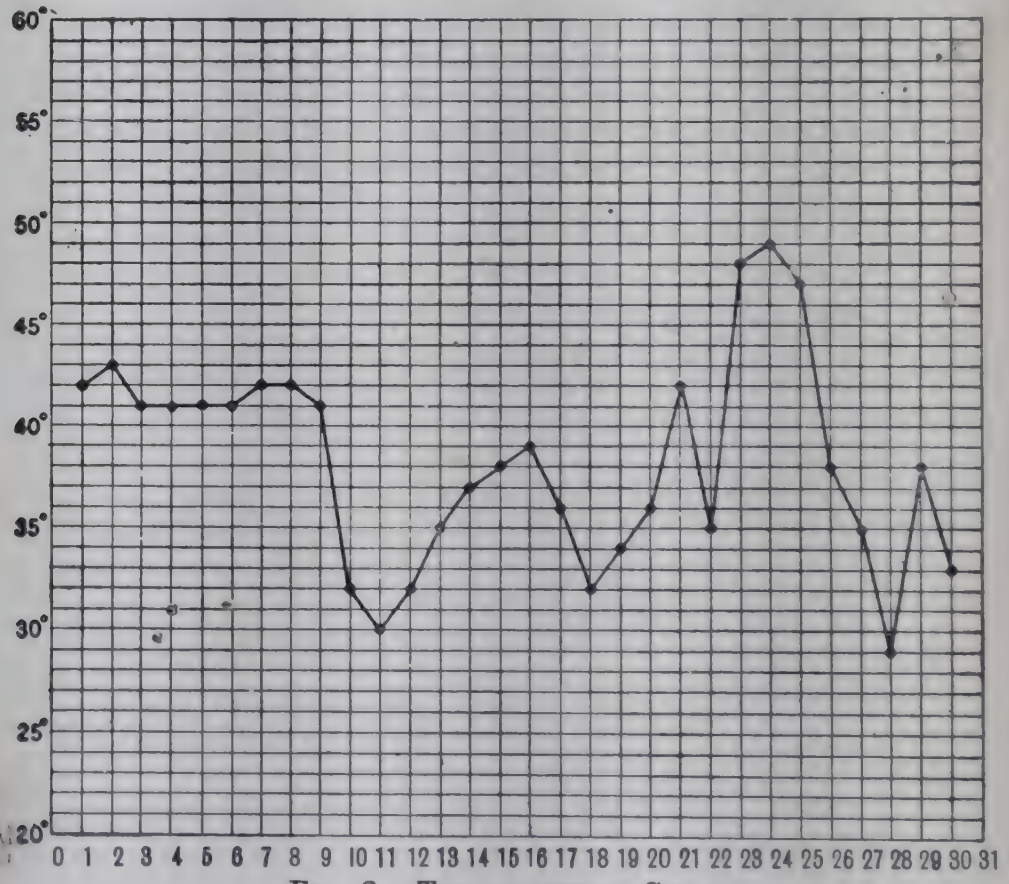


FIG. 2.—THERMOMETRIC CHART.

points is obtained. Join the points to each other. You have now a crooked line which shows the rise and fall of the thermometer at Stockholm for the month of November, 1906, at 8 o'clock each morning.

REVISION EXERCISES

1. Describe briefly a mercury thermometer. What would you expect to be the reading of a thermometer (*a*) in a comfortable room; (*b*) in water as hot as you can bear it; (*c*) in lukewarm water; (*d*) in bright sunshine in July? Q. P., 1905.

2. Draw a curve showing the rise and fall of the thermometer at Liverpool during the month of November, 1906. The readings were taken at 8 a.m.

Nov. 1	47° F.	Nov. 16	43° F.
„ 2	48° F.	„ 17	48° F.
„ 3	37° F.	„ 18	37° F.
„ 4	40° F.	„ 19	40° F.
„ 5	46° F.	„ 20	41° F.
„ 6	37° F.	„ 21	48° F.
„ 7	48° F.	„ 22	57° F.
„ 8	47° F.	„ 23	53° F.
„ 9	46° F.	„ 24	46° F.
„ 10	40° F.	„ 25	40° F.
„ 11	41° F.	„ 26	43° F.
„ 12	43° F.	„ 27	48° F.
„ 13	40° F.	„ 28	50° F.
„ 14	36° F.	„ 29	53° F.
„ 15	45° F.	„ 30	46° F.

CHAPTER II

MAXIMUM, MINIMUM, AND MEAN TEMPERATURES

So far we have considered how to read and record the temperature at a particular time at a given place. But the temperature varies during the day, and it may at some time during the day be hotter or colder than at the particular time chosen for reading the thermometer. We wish to know the highest and lowest temperatures for the day. To obtain these we could employ a series of watchers who should never leave the thermometer, but who should continually watch and record its movements. Then we could collect their observations, and see what had been the highest and the lowest temperatures for every period of twenty-four hours.

It is at once obvious that such a method would be both troublesome and expensive. We have, however, thermometers that are so made that we need not look at them more than once a day, and yet they tell us truly the highest and the lowest temperatures that have been reached since we last looked at them.[1]

[1] Teachers will find *Hints to Meteorological Observers* (Marriott) of great use. Six's Maximum and Minimum Thermometer can be obtained of Messrs. G. Philip & Son. See p. 161.

The highest temperature reached during the day is called the maximum temperature, and the thermometer that registers it is called a **maximum thermometer.** The lowest temperature reached during the day is called the minimum temperature, and the thermometer that records it is called a **minimum thermometer.**

There is a very common form of thermometer employed by gardeners which is called a maximum and minimum thermometer, because the maximum and minimum temperatures are both recorded on the same instrument (Fig. 3). It consists of a piece of glass tubing so bent as to give us a bulb at C and two vertical thin tubes. In C and the light part of the tubes is alcohol. In the dark part of the tube there is mercury. At *d* and *c* are two little dumb-bell shaped bodies K. To each of these is attached a small steel spring which presses against the side of the tube and keeps the index from falling from any position into which it may be pushed. The thermometer must be read at the same hour each day. Let us suppose this to be noon. At noon to-day, by means of a magnet, pull each index down until its lower end touches the thread of mercury. Then leave the thermometer until noon to-morrow. When the temperature rises, the alcohol in C expands and pushes the mercury forwards. This pushes the index *d* so that the lower end of *d* always marks the highest temperature reached since the thermometer was last set. When the temperature falls, the alcohol in C contracts and the mercury rises in the right hand tube and pushes back the index *c* so that the lower end of *c* always marks the lowest temperature reached since the instrument was last set.

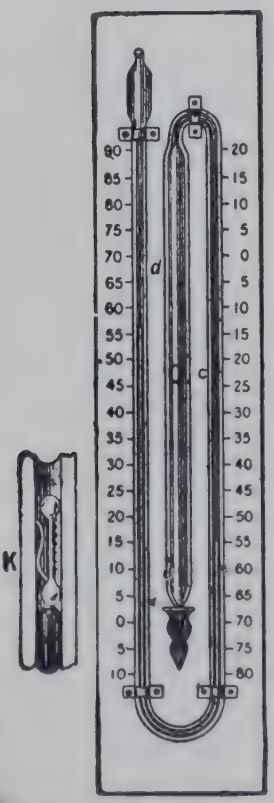


FIG. 3.—MAXIMUM AND MINIMUM THERMOMETER.

Sometimes two thermometers are used. These are then frequently both fastened on the same frame (Fig. 4). The

maximum thermometer is really an ordinary thermometer fixed horizontally (B). In the tube is a solid bit of steel. By means of a magnet, this piece of steel is made to touch the end of the mercury column. When the mercury expands it pushes the index in front of it. When it contracts, the index remains still, and so the *back* end of it marks the highest point that has been reached since the instrument was last set.

The minimum thermometer (A) contains alcohol and not mercury. It is fixed horizontally. The index is a small glass dumb-bell. When the alcohol expands it flows past the index without moving it. When the alcohol contracts on cooling, the index is drawn backwards by the film of liquid at the end of the column. The lowest temperature to which the alcohol has been exposed is therefore

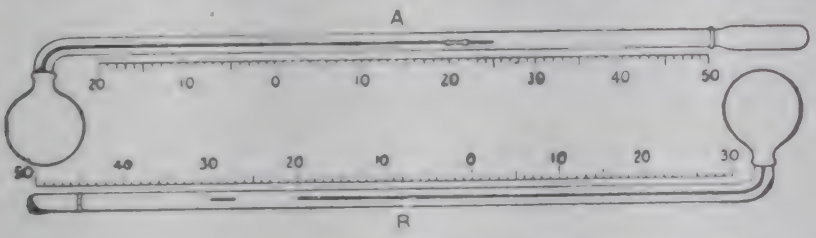


Fig. 4.—Maximum and Minimum Thermometers.

marked by the *forward* end of the index. To set the instrument it is inclined a little so that the index slides down to the end of the liquid column.

Exercise 5.—Pin up on a drawing board in your classroom or other convenient place a large sheet of squared paper. Every day, for the next twelve months, read the maximum and minimum thermometers and record the results on the paper. Join up the points obtained in this way.

Fill up also the columns headed maximum and minimum on a form like the one shown (Fig. 5). The other columns can be left blank for the present. Put the chart and the form side by side on the same board.

Mean Temperature.—If a man plays five times at cricket and makes 20, 30, 40, 10, 70 runs, his average is 34. This is found by adding together all his runs (170) and dividing the sum by the number of times he played (5). If we read the thermometer every hour during the day,

METEOROLOGICAL REGISTER.

Kept at_____ For the Month of_____ 19__

Date	Barometer	Wind	Rainfall	Thermometer		Date	Barometer	Wind	Rainfall	Thermometer	
				Max.	Min.					Max.	Min.
1						17					
2						18					
3						19					
4						20					
5						21					
6						22					
7						23					
8						24					
9						25					
10						26					
11						27					
12						28					
13						29					
14						30					
15						31					
16											

FIG. 5.

add the 24 readings and divide by 24 we shall obtain the average reading. We might call this the **mean tempera-**

ture for the day. The mean temperature would be obtained more accurately by reading the thermometer every half hour, or 15 minutes, or even every minute, but this would entail a great deal of labour, and it is found that the average of the maximum and minimum temperatures for a day is very nearly the mean temperature. Thus, if the maximum temperature for a day be 68° F., and if the minimum temperature for the same period be 50° F., then the mean temperature is 59° F.

Exercise 6.—Mark upon your chart each day not only the maximum and the minimum temperatures, but also the mean temperature. Indicate this by a dotted line.

REVISION EXERCISES

1. Define: maximum temperature, minimum temperature. How is the mean daily temperature found?

2. The following table gives the maximum and minimum temperatures for the first six days of November, 1906, at Aberdeen. Copy the following table, and fill up the column showing the mean temperature and draw three curves showing the result.

Date.	Maximum Temperature.	Minimum Temperature.	Mean Temperature.
Nov. 1 . . .	52° F.	48° F.	
„ 2 . . .	51° F.	48° F.	
„ 3 . . .	51° F.	48° F.	
„ 4 . . .	51° F.	47° F.	
„ 5 . . .	50° F.	40° F.	
„ 6 . . .	49° F.	39° F.	

CHAPTER III

MEAN TEMPERATURE—ISOTHERMS—TEMPERATURE AND LATITUDE

If we add together all the mean temperatures for each day of the month, and then divide the sum by the number of days in the month, we get the **average temperature** for the month. If we add together the mean temperatures for each day of the year, and then divide the sum by 365, we get the **average temperature** for the year. If we

add together the average temperatures for, say, ten years, and then divide the sum by ten, we get the **mean annual temperature** for that period.

The following table gives the average mean monthly temperature for each month of the year at Edinburgh. It was found by adding together the mean monthly temperatures for each month for a period of twenty-four years, and then dividing the sum by twenty-four.

January	37° F.	July	58° F.
February	39° F.	August	57° F.
March	40° F.	September	53° F.
April	45° F.	October	46° F.
May	49° F.	November	40° F.
June	55° F.	December	38° F.

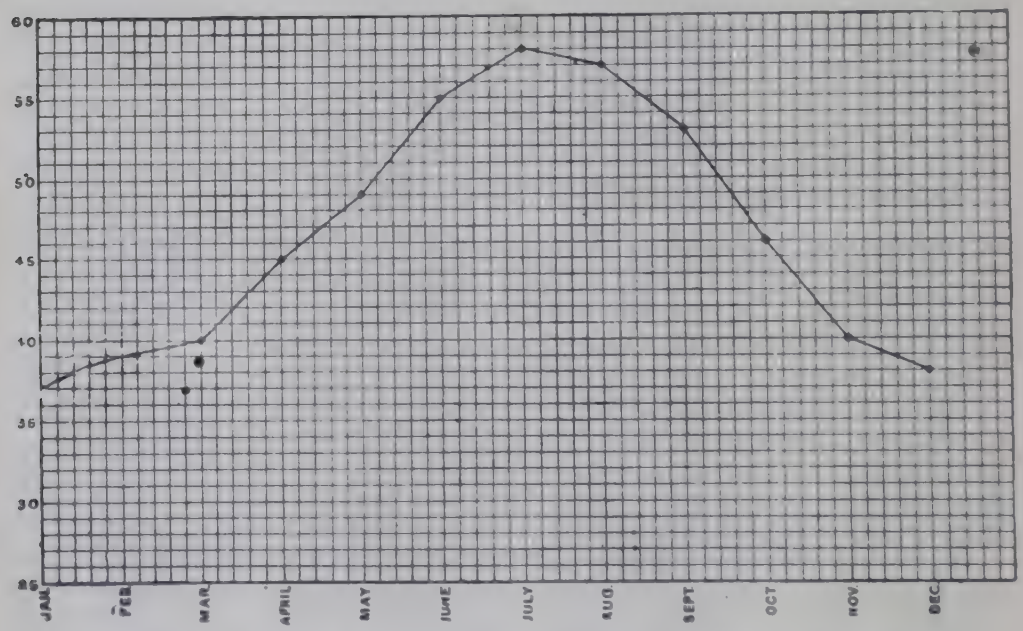


FIG. 6.—CURVE SHOWING VARIATION OF TEMPERATURE.

The curve given below (Fig. 6) shows the variation in temperature at Edinburgh as given by the above figures. Notice the gradual way in which the temperature rises and falls throughout the year.

Certain places on the earth's surface have the same temperature. If these places be joined by lines we get lines called **isotherms** or **isothermal lines**, that is, lines of equal temperature (*isos* = equal, *therme* = heat). Iso-

thermal lines can also be drawn showing the mean annual, monthly, or daily temperatures at different places.

In Fig. 7 we have a map of the British Isles on which isotherms are drawn connecting all places that have the

FIG. 7.—BRITISH ISLES: MEAN ANNUAL TEMPERATURE.

same mean annual temperature. In some respects these lines are misleading, especially if they suggest to you that places on the same isotherm have anything like the same climates. One place may have a very hot summer and a very cold winter and its mean annual temperature be just

the same as that of another place with a fairly cool summer and a fairly mild winter. But the isotherms have a certain value, and teach one particular lesson.

Exercise 7.—What is (*a*) the highest temperature shown, (*b*) the lowest? Between what isotherms do the British Isles lie? In which general direction do the isotherms run? Speaking generally, if you travel northwards from the equator, does the mean annual temperature rise or fall? The distance of any place north or south of the equator is

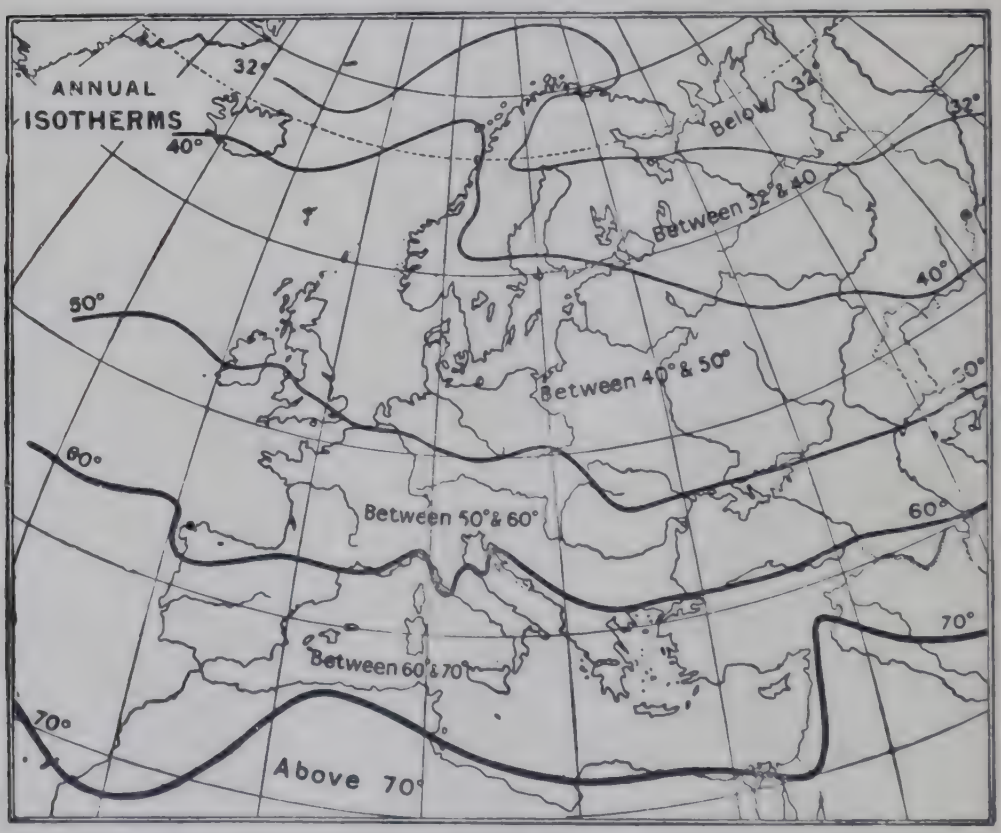


FIG. 8.—EUROPE: MEAN ANNUAL TEMPERATURE.

called its **latitude.** Judging from this map only, what connection would you say existed between temperature and latitude?

Exercise 8.—Examine Fig. 8, which shows the isotherms of mean annual temperature for Europe. Note again the general direction of the isotherms and the way the temperature rises or falls as the latitude increases.

FIG. 9.—THE WORLD: MEAN ANNUAL TEMPERATURE.

Exercise 9.—Lastly, in Fig. 9 we have the isotherms of mean annual temperature drawn for the whole of the world. What change in temperature takes place as we go either north or south of the equator ?

We are finally led to the conclusion that the temperature of a place depends on its latitude—the higher the latitude the lower the temperature. Hence we should expect, as indeed we find is the case, that the hottest regions of the earth are on or near the equator and the coldest regions at or near the poles.

But observe that these lines are not parallel in any of the maps. If the latitude were the only thing that affected the temperature, then the isotherms would be lines parallel to the equator. As this is not the case, there must be other causes which affect the climate, and some of these we have now to discover.

REVISION EXERCISES

1. Define isotherms.
2. Define latitude.
3. State the connection between 1 and 2.
4. Draw a map of your own country, showing a few isotherms of mean annual temperature to prove the connection stated in 3.

CHAPTER IV

TEMPERATURE AND NEARNESS TO THE OCEAN

We saw in the last chapter that there is a close connection between the temperature of a place and its distance from the equator, and that if the climate of a place depended on nothing else but its distance from the equator, then the isothermal lines would all be parallel to the equator. As these lines are not parallel to the equator something else besides latitude must influence temperature.

Exercise 10.—Find the positions of Paisley and Rothesay. They are in nearly the same latitude. Below are given the mean monthly temperatures for twelve months of the year at the two places.

Month.	Paisley. Mean Monthly Temperature.	Rothesay. Mean Monthly Temperature.
January	38·9° F.	38·9° F.
February	38·9° F.	39·6° F.
March	40·3° F.	40·7° F.
April	45·0° F.	45·3° F.
May	50·7° F.	49·9° F.
June	56·4° F.	55·2° F.
July	58·7° F.	57·6° F.
August	58·0° F.	56·7° F.
September	54·4° F.	53·7° F.
October	47·7° F.	47·5° F.
November	42·3° F.	42·6° F.
December	39·5° F.	40·0° F.

Plot two curves on the same paper showing the above variations in temperature.

Now observe :

i. In the winter it is colder at Paisley than it is at Rothesay.

ii. In the summer it is hotter at Paisley than it is at Rothesay.

iii. Paisley is an inland town.

iv. Rothesay is on the coast.

The difference between the mean temperatures of the hottest and the coldest months of the year is called the **annual range of temperature.** Where this range is small at any place, the climate is said to be **equable ;** where it is great, the climate is said to be one of **extremes.**

Which of the two places, Rothesay or Paisley, has the more equable temperature ? What connection is suggested as existing between the position of a place with regard to its nearness to the sea and its range of temperature ?

Exercise 11.—Let us test the matter further. On the map of Europe, find the positions of London and Orenburg (Russia). They are in nearly the same latitude. The

mean monthly temperatures at the two places for four different months of the year are given below.

	London.	Orenburg.
January	3·5° C.	−15·3° C.
April	9·6° C.	3·2° C.
July	17·9° C.	21·6° C.
October	10·7° C.	3·8° C.

Plot two curves on the same paper showing these results. Allow about $1\frac{1}{2}$ in. horizontally for each of the months and about $\frac{2}{10}$ in. vertically for each degree of temperature.

Notice again :

i. It is colder in the winter at Orenburg than it is at London.

ii. It is warmer in the summer at Orenburg than it is at London.

iii. Orenburg is an inland town.

iv. London is near the sea.

Which has the more equable climate ?

The sea is more slowly heated than the land ; hence in summer the presence of the sea tends to keep a place cool. The sea loses its heat more slowly than the land ; hence in winter the presence of the sea tends to keep a place warm.

Countries like the British Isles which are near the sea enjoy what is called a **maritime** or **oceanic** climate. Countries such as Hungary have what is called a **continental** climate, which is subject to great extremes of heat and cold. Paris is farther south than London but its winter is much more severe. Why is this ? Would you expect Paris or Moscow to have the more equable climate ? Why ? Find on your map of Europe six large towns that have an oceanic climate and six that have a continental climate. Would you expect Denmark to have a mild climate or a climate of extremes ?

In trying to discover what the climate of a place is like from an examination of a map, you must not forget to take

into consideration all the causes that affect the climate. For instance, Iceland is surrounded by sea. You must not therefore conclude that it has a mild climate. If you take its latitude into consideration you will not be surprised to find that its climate is so excessively cold that agriculture in Iceland is practically impossible. At the same time do not forget that the annual range of temperature in Iceland is smaller than it would be if Iceland were in the same latitude but situated in the interior of a continent.

Exercise 12.—Find the following places on your map of Europe and fill up the column that has been left blank. Notice carefully the position of these places with regard to their nearness to the sea and compare these with the annual range of temperature for each place.

Place.	Mean Temperatures.				Annual Range of Temperature.
	January.	April.	July.	October.	
London . .	3·5° C.	9·6° C.	17·9° C.	10·7° C.	
Brocken . .	— 5·4° C.	0·7° C.	10·7° C.	4·0° C.	
Leipzig . .	— 1·2° C.	8·3° C.	18·0° C.	9·0° C.	
Breslau . .	— 2·2° C.	7·9° C.	18·5° C.	9·4° C.	
Warsaw . .	— 4·4° C.	7·0° C.	18·6° C.	7·8° C.	
Kursk . . .	— 9·9° C.	4·7° C.	19·3° C.	6·4° C.	
Saratov . .	—10·2° C.	4·6° C.	21·7° C.	5·7° C.	
Orenburg . .	—15·3° C.	3·2° C.	21·6° C.	3·8° C.	

Draw on one piece of squared paper curves of mean temperature for all the above places, or, if time is short, for London, Leipzig, and Saratov.

REVISION EXERCISES

1. What are the differences between a typical oceanic climate and a typical continental climate? What are the causes of the differences? Illustrate your answer by reference to particular regions. Show that while on the whole the climate of the British Isles is oceanic, the continental type is approached in certain districts. O. J., 1904.

2. Compare the climate of Central Russia with that of Ireland, and point out the causes of any differences you describe. O. J., 1898.

CHAPTER V

TEMPERATURE AND ALTITUDE—EFFECT OF SLOPE OF LAND, OCEAN CURRENTS, MOUNTAIN CHAINS AND WINDS

Exercise 13.—Find on a map of England the positions of Dartmoor (Devonshire) and Osborne (Cowes) in the Isle of Wight. These two places are in nearly the same latitude and on that account might be expected to have about the same mean monthly temperatures. Both places are near the sea, so that on this account also we might expect the mean monthly temperatures of the two places to be alike. As a matter of fact there are considerable differences between the mean monthly temperatures of Dartmoor and Cowes.

	Dartmoor.	Osborne.
January	37·0° F.	40·0° F.
February	38·0° F.	41·4° F.
March	39·1° F.	43·2° F.
April	43·4° F.	48·8° F.
May	47·6° F.	53·8° F.
June	53·3° F.	60·1° F.
July	56·1° F.	63·4° F.
August	55·9° F.	63·0° F.
September	53·0° F.	59·3° F.
October	47.6° F.	52·7° F.
November	40·8° F.	44·5° F.
December	38·3° F.	41·1° F.

Plot on the same piece of squared paper the curves showing the above results. We have here two places, in nearly the same latitude and both near the sea, and yet one place is always warmer than the other. This suggests that there must be yet another cause that influences the temperature of a place.

Notice:

i. Dartmoor is on high ground. It is 1,372 ft. above the level of the sea.

ii. Osborne (Cowes) is on lower ground. It is only 172 ft. above the level of the sea.

This suggests that temperature may be affected by altitude. This is really a matter of common experience. If we start at the foot of a mountain and climb to the

summit, we find that it gets colder as we ascend, at the rate of about 1° F. for every 300 ft. of ascent. Find on the map of Scotland the positions of Ben Nevis and Fort William. They are in nearly the same latitude, and both are near the sea, but the summit of Ben Nevis is 4,407 ft. above sea-level, and Fort William is only about 42 ft. above sea-level. What will be about the average difference between the mean monthly temperatures of the two places ?

If the temperature of a place is always at or below 32° F., then the snow and ice at that place cannot melt. If we draw a line at the level above which snow is always present, we get what is called the **snow-line.** In the British Isles there is no snow-line, as the snow practically always melts in the summer even on the tops of our highest mountains. But in the Swiss Alps it is always below 32° F. at a height of about 8,800 ft. on the North slope and 9,000 ft. on the South slope. Above that height snow lies all the year round. Near the Mediterranean, while the tops of the Alps are covered with snow, there is at the foot of the mountains a warm district, the Riviera, where invalids go in great numbers in the winter to escape the cold of the more northerly regions.

In order to compare readings of temperatures taken at different heights it is usually necessary to calculate what each reading would be if the heights were the same. The height usually chosen is sea-level, and the temperatures so calculated are said to be "reduced to sea-level." Maps may then be constructed comparatively easily. Maps showing actual distribution of temperature, taking height into account, require many more observations, and are more difficult to construct. Examples of both are given in this book.

Summing up the lessons we have already learned, we see that the temperature of a place depends on :

i. Its latitude. The nearer a place is to the equator the warmer it is.

ii. Its altitude. The higher a place is above the sea-level the colder it is.

iii. Its distance from the sea. The nearer a place is to the sea the more equable is its temperature.

But these things are not the only ones that affect temperature. We may note here at least three others.

i. **The Slope of the Land.**—Land which slopes towards the sun is warmer than land which slopes away from the sun, as may be seen by considering the height of the snow-line on the northern and southern sides of the Alps.

ii. **Ocean Currents.**—There are in the oceans certain currents of either cold or warm water, and these play a very important part in affecting the climate of the shores near which they flow.

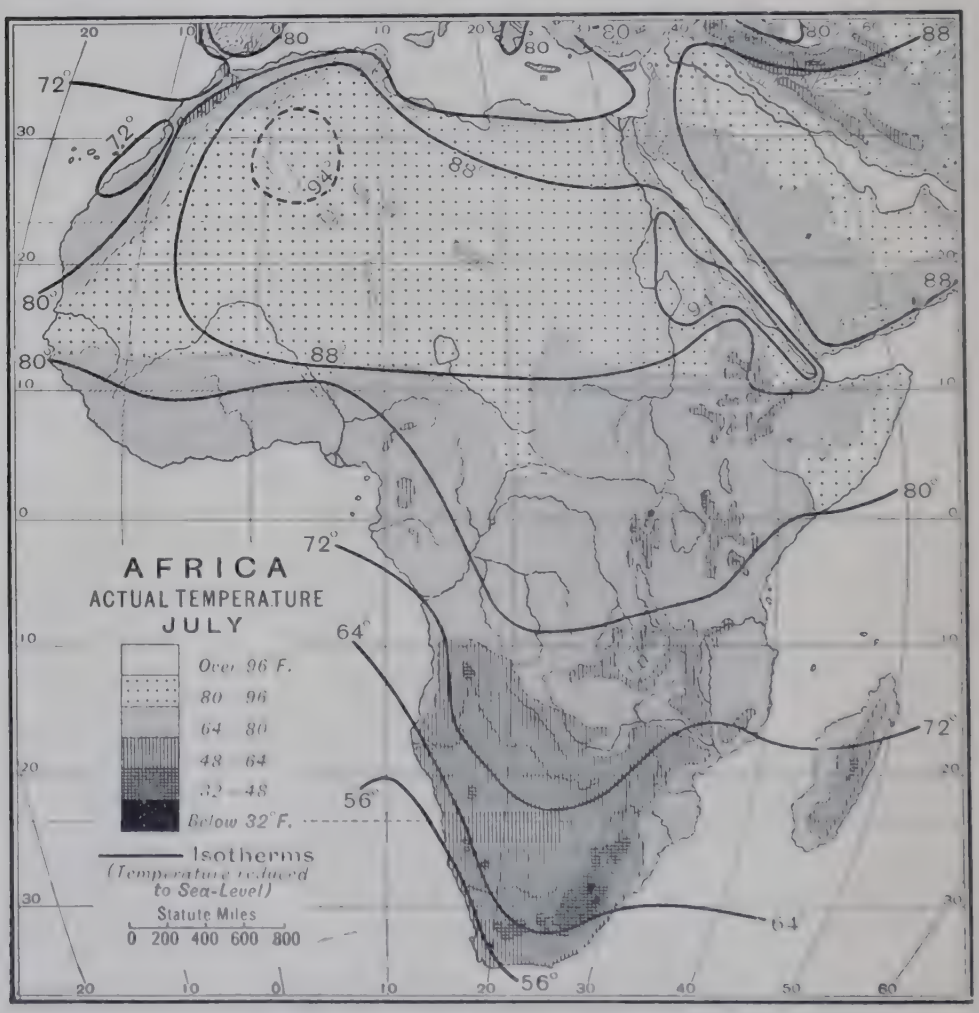


FIG. 10.—AFRICA: JULY ISOTHERMS.

Exercise 14.—Fig. 10 shows the July isotherms for Africa. Consider isotherm 72° F. Notice that on the east coast the water, say 20° S. of the equator, has a mean July temperature of 72° F., but that on the west coast it is water near 5° S. that has the same mean July temperature. The reason for this is, that on the east coast a warm current of water flows south from the equator, while on the west coast

a cold current flows north from the Antarctic. Many other examples of this can be detected by examining maps of other continents showing either mean January or mean July temperatures.

iii. **The Direction of the Mountain Chains.**—It is warmer on the leeward than on the windward side of a mountain range.

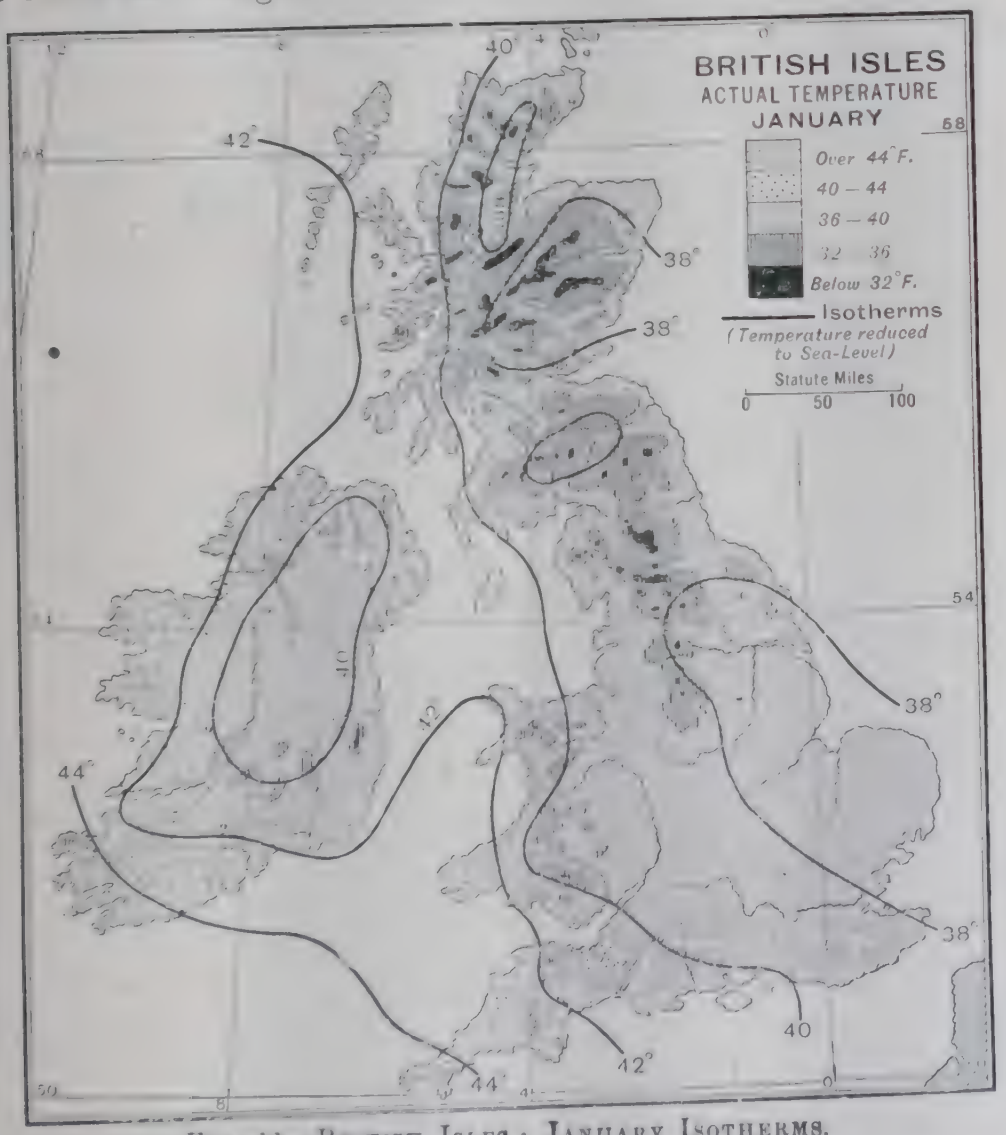


Fig. 11—British Isles : January Isotherms.

iv. **Prevailing Winds.**—**Exercise 15.**—Examine Fig. 11, which shows the isotherms for January for the British Isles. Speaking roughly, which way do the isotherms run? It would seem as though latitude had little to do with the matter, for it is as warm in the north-west corner of Scot-

land as it is in the Isle of Wight. Trace out isotherm 40. What do you notice about the isotherms (*a*) to the east of this line, (*b*) to the west? Which are (*a*) the the hottest, (*b*) the coldest parts of the British Isles in winter.

This is curious, but the explanation is not difficult if we

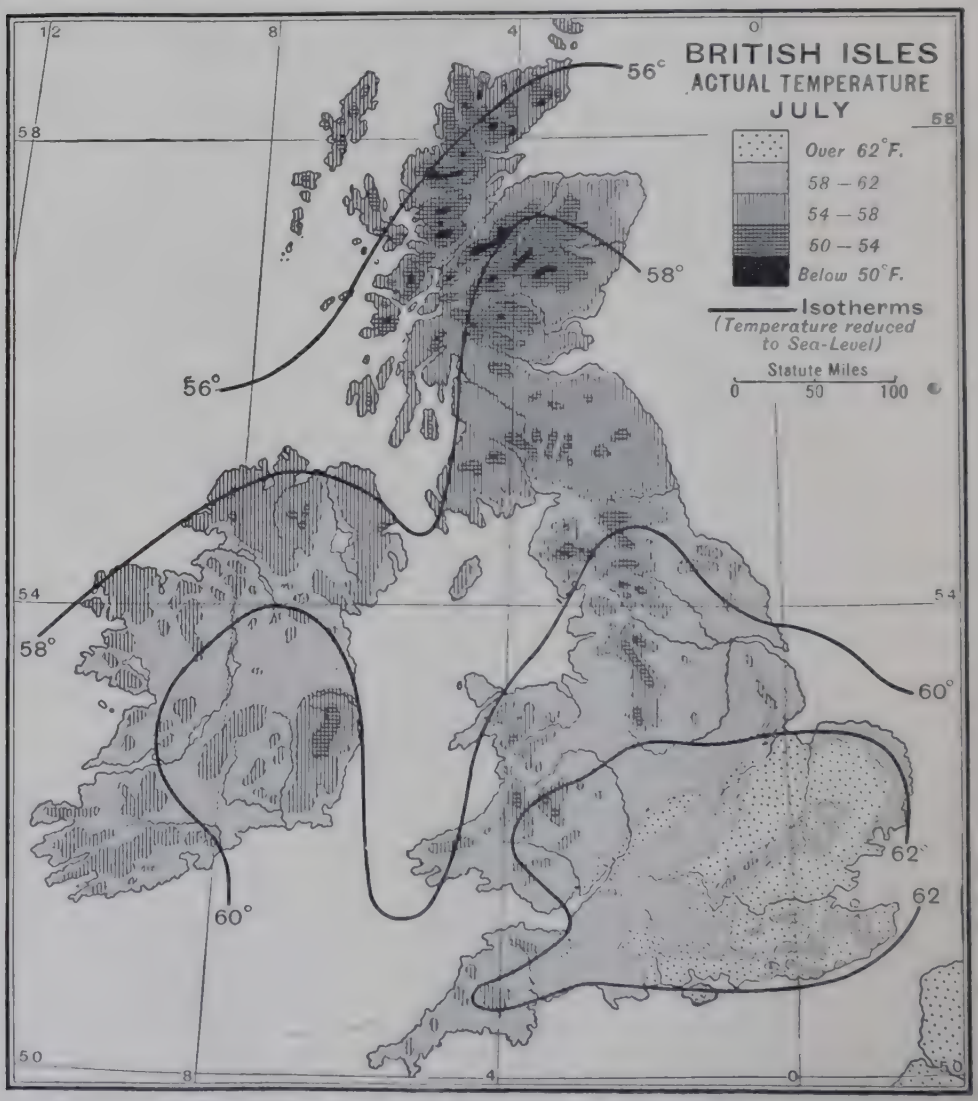
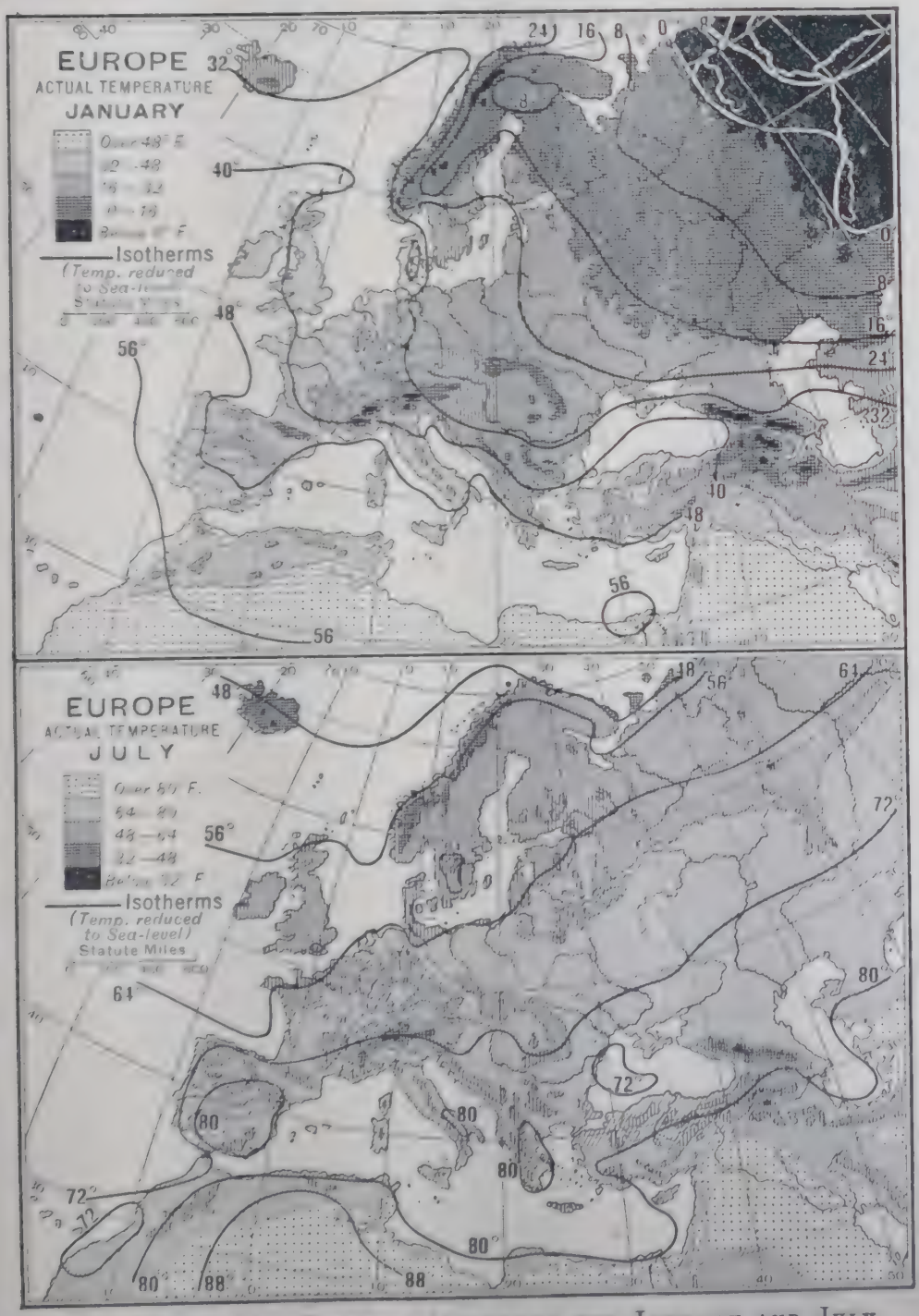


FIG. 12.—BRITISH ISLES: JULY ISOTHERMS.

remember that the prevailing winds in winter are the west and south-west. Do they blow over land or water? Is this water, in the winter, hotter or colder than the land in the same latitudes? Will the winds then be relatively warm or cold? What will be their effect all up the west of

the British Isles? Now consider the east winds. The North Sea is so small and shallow, that we may neglect it for the present. Do the east winds blow then over land or water? Will this land in the winter be hot or cold? Will



FIGS. 13 AND 14.—EUROPE: ISOTHERMS FOR JANUARY AND JULY.

the winds be hot or cold? What effect will they have on the east coast?

Exercise 16.—Examine Fig. 12, which shows the isotherms for July for the British Isles. Which way do the isotherms run now? Is the effect of latitude shown here? Which is the warmest part? What will the winds from the Continent be like in July—hot or cold? Which part of the British Isles is nearest the Continent? Is there any connection between the temperature of this part and the temperature of the winds from the Continent? Notice isotherm 60°. Why does it bend north over the land and south over the water?

Exercise 17.—Examine Fig. 13. For what month are the isotherms drawn? Name the countries crossed by the isotherms 48, 32, 8. What countries have the same average temperature as England? Are they farther north or south or in the same latitudes? Account for this.

Exercise 18.—Examine Fig. 14. For what month are the isotherms drawn? Why does isotherm 72° travel away to the north-east? What parts of Europe lie between the same isotherms as the British Isles? Are they in the same or other latitudes? Account for this.

What is the annual range of temperature at a spot about lat. 50 N. long. 50 E.? Why is it so great? What is the range in the north-west corner of Spain? Why is it comparatively so small?

REVISION EXERCISES

1. In Figs. 11 and 12 (British Isles) the average isotherms for the months of January and July are drawn. Explain the difference between the form and the direction of the isotherms in the two maps. C. S., 1903.

2. Compare the climates of south-east and south-west England (say of Kent and Cornwall) in summer and in winter, and give reasons for any differences. L. J. S., 1906.

3. On what parts of the coast of the British Isles would you expect to find (*a*) a mild climate in winter; (*b*) a cool climate in summer? Give reasons for your answers. C. J., 1904.

4. What part of the British Isles has the highest average temperature and what part has the lowest (*a*) in January, (*b*) in July? In each case give a reason. C. S., 1906.

5. What is an isotherm? Explain how an annual isothermal chart is constructed, stating what observations have to be made.

On such a chart of the whole world it is noticed that the isotherms run approximately in the direction of the parallels of latitude. Explain this fact, and state (with reasons) any marked exception to it that you know of. O. S., 1910.

CHAPTER VI

THE PRESSURE OF THE AIR

We move about so easily in the air that surrounds us that we rarely realize how heavy it is. Suppose we have a box which is 1 foot long, 1 foot broad, and 1 foot high. Suppose that this box is at the sea-level and that the temperature is a medium one. Then the air in the box weighs about 1¼ ounces. The weight of the air in a large room is very great. It has been calculated that the weight of the air in Westminster Hall is nearly 75 tons!

Imagine that you have a box whose base possesses an area of 1 square inch. Let the sides of the box be so long that they rise from the sea-level to the uppermost limits of the air. Then the air in such a box weighs about 15 pounds. Hence the air is pressing down on every square inch of the earth's surface with a pressure equal to the weight of 15 pounds. This is usually expressed by saying that the pressure of the air is about 15 pounds to the square inch.

Exercise 19.—Take a tube about 36 inches long and closed at one end (Fig. 15). Fill it with mercury and invert it in a bowl of mercury. The mercury in the tube falls a little. Some of it runs out of the tube into the bowl The remainder of the mercury in the tube does not run out, and yet the bottom end of the tube is open. The mercury in the tube is pressing down with all its might and is trying to get out. But if it ran out of the tube into the dish, the level of the mercury in the dish would have to rise, and in rising, the mercury in the dish would have to lift up all the air which is pressing down on its surface. When the weight of the mercury in the tube is greater than the weight of the air, some of the mercury runs out. When the weight of the air is greater than the weight of mercury it pushes some of the mercury back into the tube. When the weight of the air is equal to the weight of the mercury in the tube there is no motion. If the pressure of the air changes the length of the mercury column changes. We could tell the amount of the pressure at the open end of the column by weighing the mercury in the tube. We do not, however,

weigh the mercury. We measure the length of the mercury in the tube and we speak of the pressure of the air as being equal to so many inches of mercury. The instrument used for measuring the pressure of the air is called a **barometer** (Fig. 16). In its simplest form it consists of a long thin tube filled with mercury and standing in a vessel con-

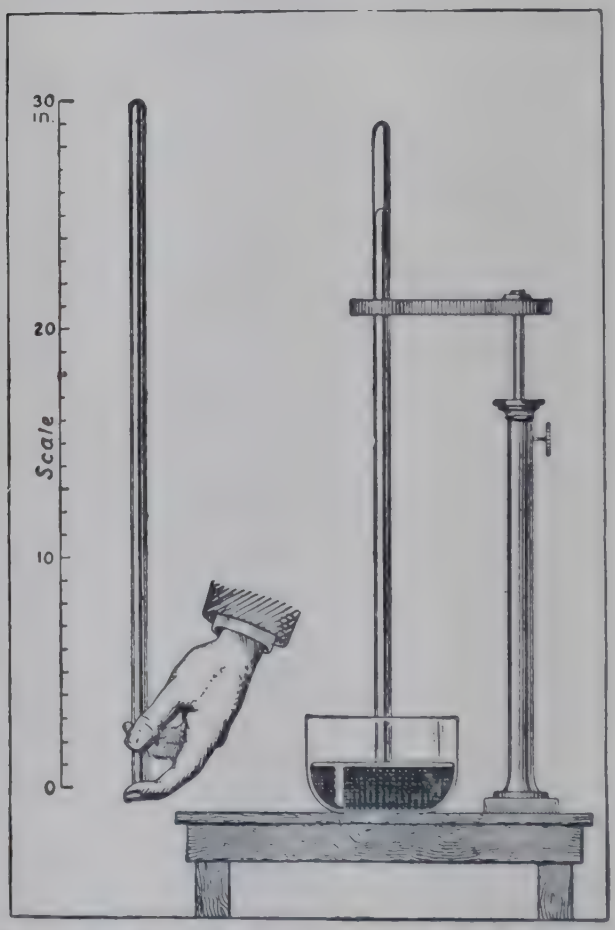


FIG. 15.—THE PRINCIPLE OF THE BAROMETER.

FIG. 16.—BAROMETER.

taining mercury. By its side is a scale from which we can read the length of the column.

Exercise 20.—In future read "the height of the barometer" each day, at the same time that you read the thermometer. Pin up a sheet of squared paper on a drawing board and plot the results throughout the school year. Fill up also column 1 of the Meteorological Register shown in Fig. 5. The rise and fall of the barometer is not very great, so that to

make the results very clear, you had better allow one-tenth of an inch on your squared paper, to represent one-hundredth of an inch on the barometer. Below is given a baro-

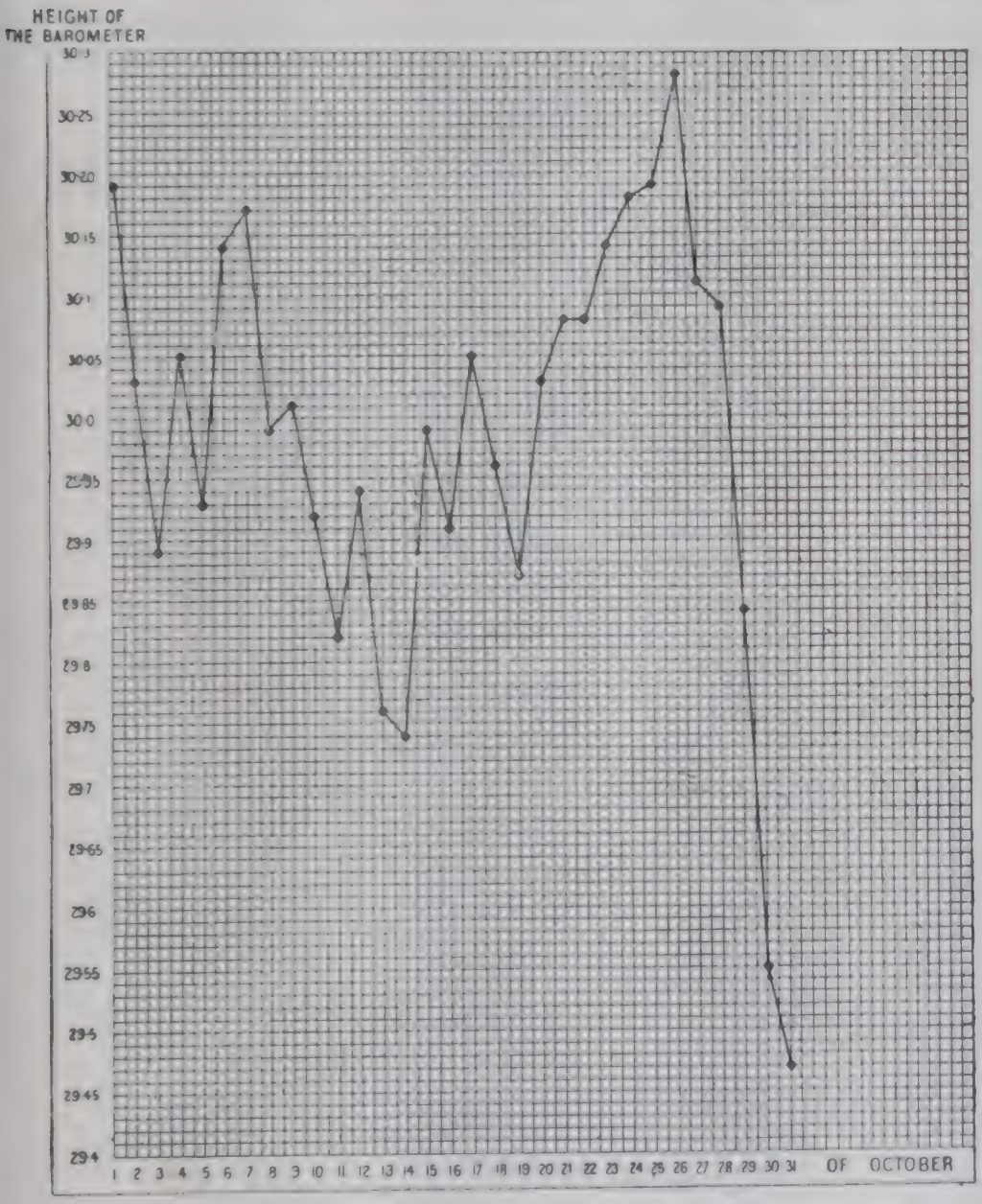


FIG. 17.—GRAPHIC CURVE SHOWING VARIATION IN THE HEIGHT OF THE BAROMETER.

metric chart showing the height of the barometer at Paris for the month of October, 1906 (Fig. 17). The readings were taken at 7 a.m.

Oct.	1	30·19 in.		Oct.	17	30·05 in.	
,,	2	30·03 ,,		,,	18	29·96 ,,	
,,	3	29·89 ,,		,,	19	29·87 ,,	
,,	4	30·05 ,,		,,	20	30·03 ,,	
,,	5	29·93 ,,		,,	21	30·08 ,,	
,,	6	30·14 ,,		,,	22	30·08 ,,	
,,	7	30·17 ,,		,,	23	30·14 ,,	
,,	8	29·99 ,,		,,	24	30·18 ,,	
,,	9	30·01 ,,		,,	25	30·19 ,,	
,,	10	29·92 ,,		,,	26	30·28 ,,	
,,	11	29·82 ,,		,,	27	30·11 ,,	
,,	12	29·94 ,,		,,	28	30·09 ,,	
,,	13	29·76 ,,		,,	29	29·84 ,,	
,,	14	29·74 ,,		,,	30	29·55 ,,	
,,	15	29·99 ,,		,,	31	29·47 ,,	
,,	16	29·91 ,,					

Add these figures together and find the average pressure at 7 a.m. in Paris during October, 1906.

Why does the pressure of the air vary continually at the same place? There are two main reasons.

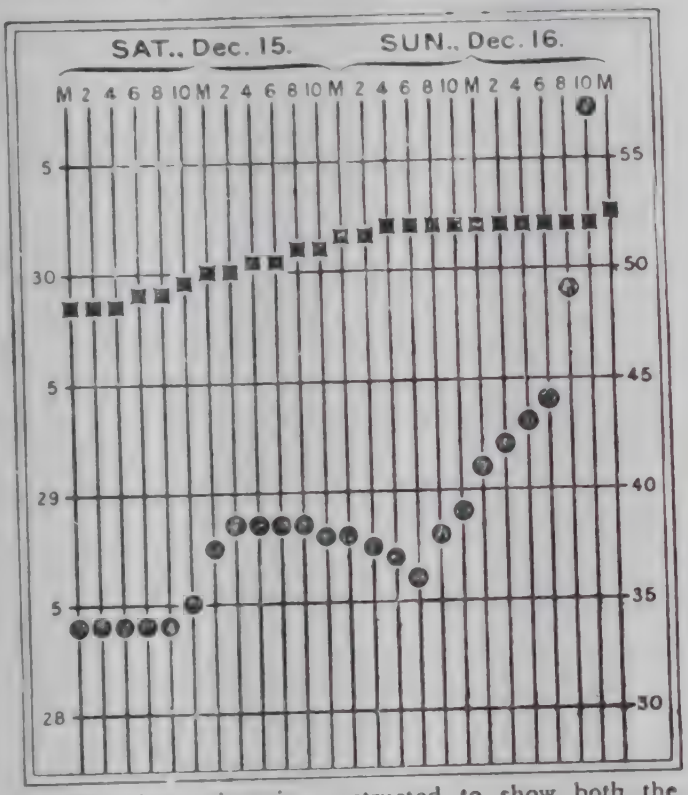
i. **Temperature.**—When air is heated it expands. If we take our box, which holds 1 cubic foot of air, and heat it, some of the air will be driven out. Therefore 1 cubic foot of air at the higher temperature will weigh less than 1 cubic foot of air at the lower temperature. On the other hand, if we cooled the box, the air in the box would contract and so occupy less space. Then more air would flow into the box to fill up the vacant space. Therefore the weight of air in the box would be greater at the lower temperature than at the higher temperature. We know that the temperature of the air changes from hour to hour. Therefore its pressure varies from hour to hour, and therefore the barometer which measures this pressure rises and falls.

ii. **Moisture.**—A cubic foot of air and moisture weighs less than a cubic foot of dry air, both being weighed at the same temperature. If there is much moisture in the air the pressure decreases and the barometer falls. If the air is cold and dry the pressure is greater and the barometer rises.

If we carried a barometer from the foot to the summit of Mont Blanc, what would happen? As we ascended the mountain the amount of air above us would decrease. The pressure would then be less and the mercury in the baro-

meter would fall. At a height of about 3 or 4 miles the pressure is only about $7\frac{1}{2}$ pounds per square inch, and the height of the barometer is only about 15 inches. Hence suggest a method of measuring the height of a mountain by means of a barometer.

You will find it interesting to collect from the daily papers copies of the weather reports. Paste them in your notebook. Some of these reports are accompanied by interesting charts and diagrams. The one given above (Fig. 18) is taken from the *Daily Telegraph* for December 17, 1906. It shows the variation of both the thermometer and the barometer for every two hours for two days.



The above chart is constructed to show both the barometrical and the thermometrical records for the past two days. The square dot indicates the position of the barometer, and the round dot of the thermometer, every two hours.

LATEST INDICATIONS.

"Daily Telegraph" Office, Sunday (Midnight).

Bar.	Therm.	Wind.	Weather
30.25 Steady	57°	N.N.W	Raining.

The sun rises to-day at 8.2 a.m., and sets at 3.49 p.m.

Fig. 18.—"Daily Telegraph" Weather Chart.

REVISION EXERCISES

1. Describe carefully how you would make a barometer. How do you measure the height of the mercury? Explain why the column of mercury does not run into the dish. O. P., 1906.

2. Describe the principle of the barometer. What would be the effect on its height of (*a*) slightly tilting sideways; (*b*) increased moisture of the air; (*c*) increased warmth of the air? O. J., 1905.

3. How can a barometer be used to measure the height of a mountain? Explain the principle upon which this use of a barometer depends. B. E., 1903

CHAPTER VII

ISOBARS—WINDS

We have already seen how we can draw lines on a map connecting the places which have the same mean temperature. These were called isotherms. In the same way we can draw on a map a series of lines connecting all places that have the same mean pressure, either daily, monthly,

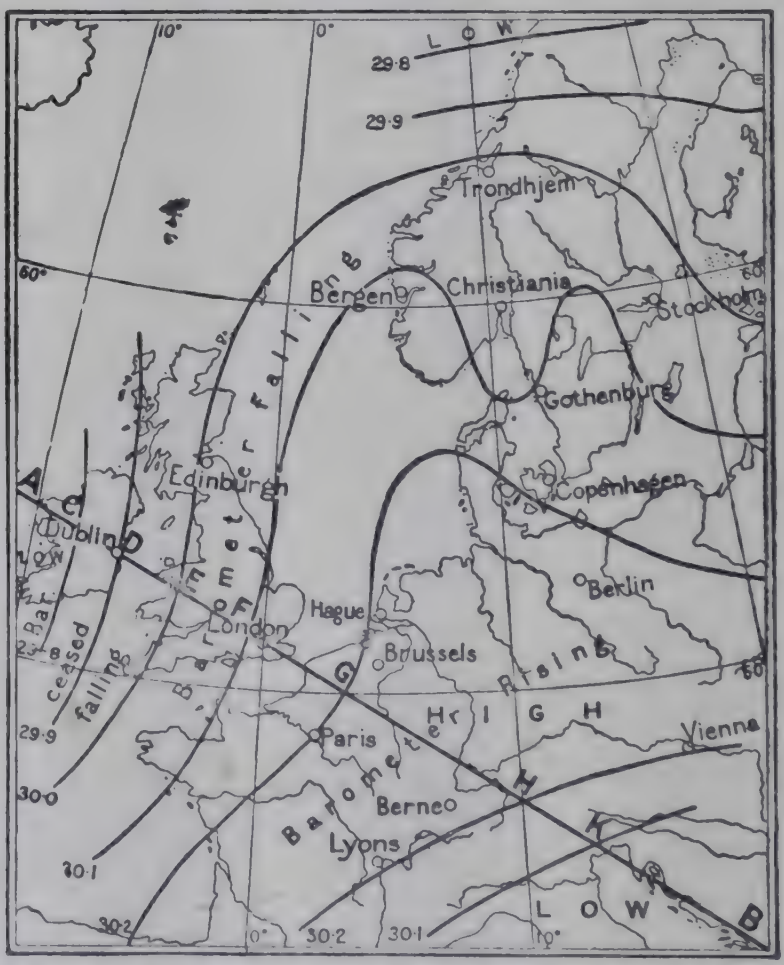


FIG. 19.—METEOROLOGICAL OFFICE CHART, OCT. 1, 1906.

or annual. Such lines are called **isobars** (*isos* = equal, *baros* = weight).

Exercise 21.—Fig. 19 shows the isobars for a given day in 1906, as drawn on a map of a part of north-west Europe. They show what the pressures would be *at sea-level* in each

case. What are (*a*) the highest pressures shown, (*b*) the lowest? What is the difference in pressure between one isobar and the next? If you carried a barometer along the isobar marked 30·2 would you expect it to rise or fall? Why? If you went from Brussels to London would the barometer rise or fall? Answer the same question for the following journeys:—Dublin to Edinburgh? Copenhagen to Berlin? Lyons to Vienna? What is the meaning of the word LOW?

Consider what would happen if you walked along the line A B. At first the barometer would stand at 29·8. By the time you got to Dublin it would have risen to 29·9. It would continue to rise for some time after you had crossed the first isobar marked 30·2, and then it would begin to

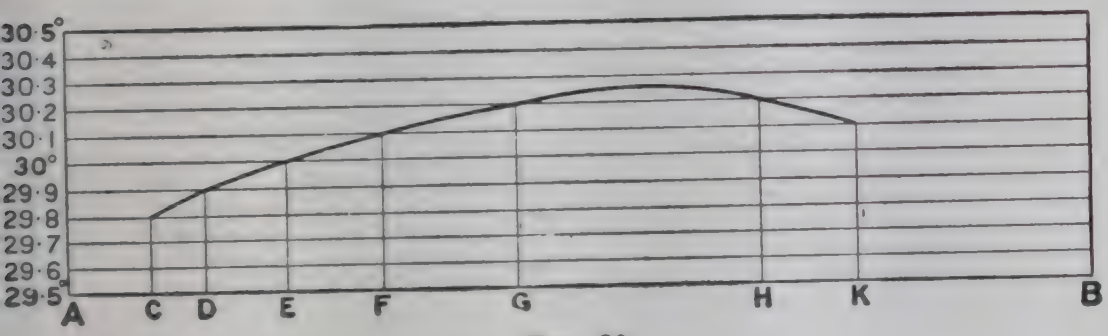


FIG. 20.

descend again as you travelled towards B. This can be represented in a diagram (see Fig. 20). A line A B has been drawn and points C, D, E, F, etc., taken at the same distances apart as in Fig. 19. At these points perpendiculars have been erected to represent the heights of the barometer at these points.

The tops of these lines have been joined, and you get a line showing what is called the **barometric gradient**, that is, the difference between the pressures at two places.

Winds.—Wind is air in motion. The air moves from a place where the pressure is high to a place where the pressure is low, just as water flows from a higher to a lower level. Therefore anything which causes the pressure of the air to vary at a given place will cause a wind. When the air in some particular area gets heated, it expands and becomes

lighter, bulk for bulk, than the colder air round it. The colder air from the surrounding area pushes under it, causing it to rise.

Exercise 22.—Refer to Fig. 19. Was the wind blowing from the Continent to the British Isles or in the opposite direction ?

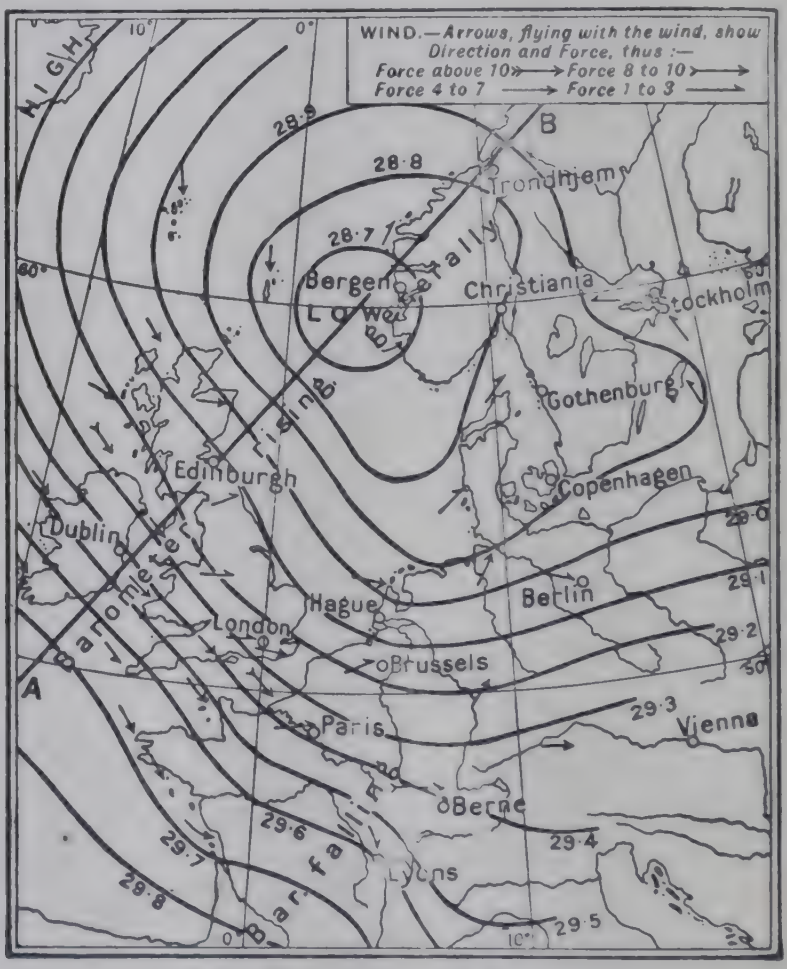


FIG. 21.—CYCLONIC SYSTEM.

Exercise 23.—Which way was the wind blowing in the south-east corner of the map ? Compare Figs. 19 and 20. Notice (*a*) where the isobars are closest together, (*b*) where the gradient is steepest. The wind is strongest where the gradient is steepest, and we see that where the isobars are close together we have strong winds, and where they are far apart we have light winds.

Exercise 24.—Fig. 21 shows the isobars drawn on a map of

a part of north-west Europe on November 2, 1910. You will notice that in this case some of the isobars form closed curves What isobar is at the centre ? As you move outward from the centre does the pressure increase or decrease ? Where is the pressure lowest ?

A system of closed curves enclosing an area of low-pressure is called a **cyclone.** From what we have previously learned, you might suppose that the winds blow directly across from one isobar to the next. This is what would happen if the earth were still; but as the earth rotates on its axis, the winds do not blow at right angles to the isobars.

Exercise 25.—Take a globe—a ball will do if the North and South Poles are marked on it. Lay a sharpened pencil on it at some place in the northern hemisphere, so that it points northwards. Notice the spot *on the wall of the room* to which the pencil points, rotate the globe slightly on its axis, and try as far as possible to keep the pencil pointing to the same spot on the wall. Keep rotating the globe till it has rotated through 30°, and keep the pencil pointing to the same spot on the wall. Does it still point north ? In what direction does it point ? Repeat the operation with the pencil pointing south to start with : in what direction does it now point ? How is the pencil turning on the globe, to the right or to the left ? Repeat both experiments with the pencil on some place on the southern hemisphere : how does it now turn, to the right or to the left ?

Air moving on the surface of the earth tends to act like the pencil. If it starts by moving northward in the northern hemisphere, when the earth rotates, it tends to keep the same direction *in space* and to turn towards the north-east; if it starts by moving southward it tends to turn towards the south-west., i.e. winds in the north hemisphere tend to turn to the right. In the southern hemisphere winds tend to turn to the left.

Thus the wind in a cyclone does not move directly across the isobars, but is always turned much more to the right in the northern hemisphere than you would expect. The winds blowing from A, B, C, which one would expect to move

across the isobars to A′, B′, C′, are in fact turned to the right to move to A″ B″ C″.

In Fig. 22 arrows are inserted to show the directions of the wind, and you will notice that on the whole the air in a cyclone has a spiral motion in a direction opposite to that of the hands of a clock. The winds move "counter-clockwise." (This applies only to the northern hemisphere. In the southern hemisphere the conditions are reversed.)

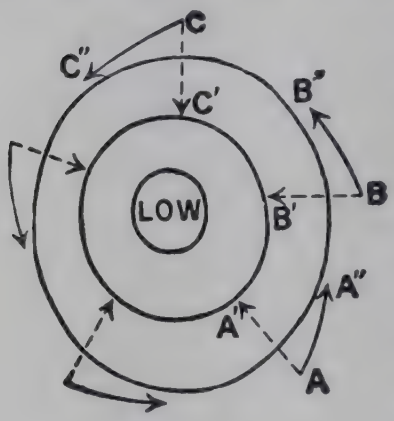


Fig. 22.

Exercise 26.—Draw a diagram to show the barometric gradient along A B in Fig. 21. It is not necessary to erect perpendiculars as in Fig. 20. Merely plot the heights of the barometer and join them by a straight line. Where were the winds strongest? Do the diagram and the map agree on this point?

Exercise 27.—In Fig. 23 we have a series of four maps showing the passage of a cyclone across our islands. Where did the cyclone come from? In which direction did it travel? About how far did the centre of the cyclone travel during the period represented? What was the rate at which the centre travelled? How did the barometer move (*a*) in front, (*b*) at the centre (*c*) at the rear of the area of low pressure?

Exercise 28.—Consider the following places: Dublin, Edinburgh, London, Copenhagen, and fill in the following table.

Place.	Date.	Hour.	Pressure.	Direction of Wind.

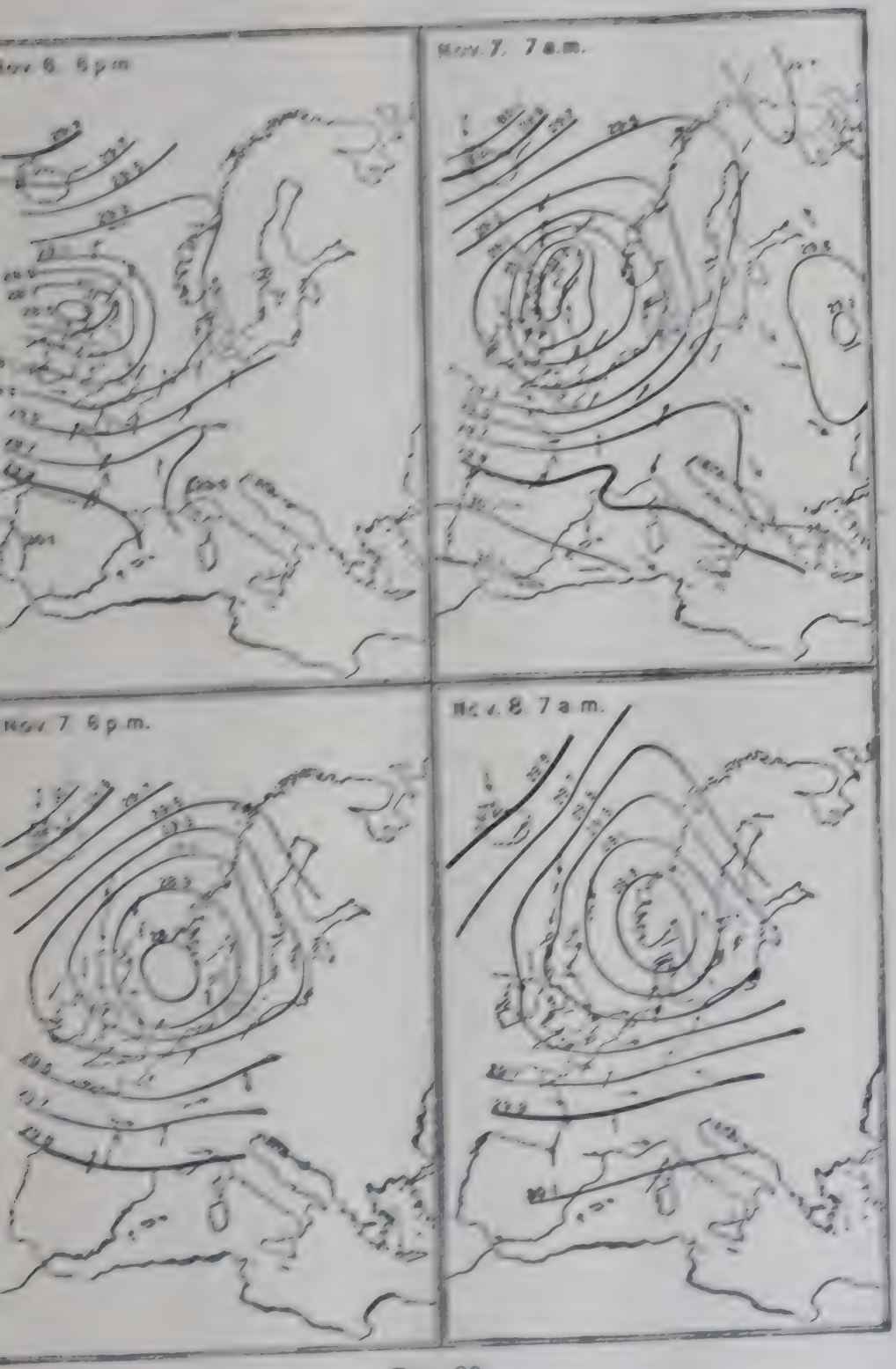


FIG. 23

Now southerly or westerly winds are warm and raise the temperature of the places to which they blow, while northerly or easterly winds are cold and lower the temperatures of the places to which they blow. Hence say whether it got warmer or colder at each of the above places at the hours mentioned.

Generally, in England, when a cyclone exists it comes

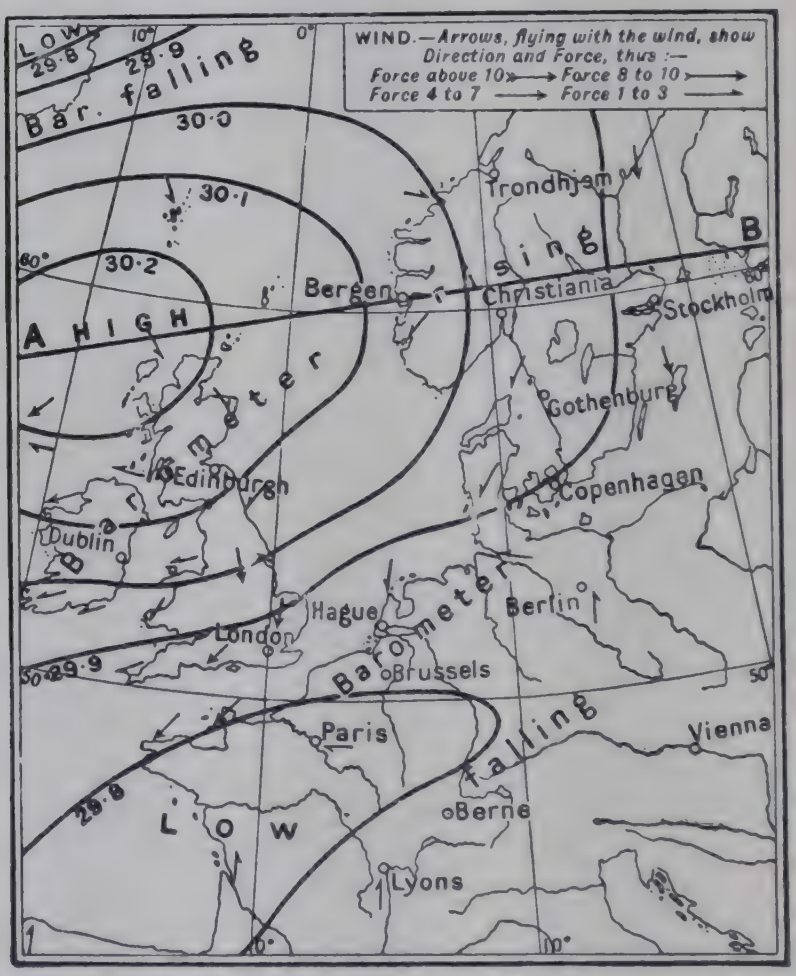


FIG. 24.—METEOROLOGICAL OFFICE CHART, OCT. 19, 1906.

from the south or south-west; and rain falls on the east side of the cyclone. When the cyclone passes the barometer rises, the wind becomes north or north-west and the weather becomes fine. In a cyclonic area winds are pushed upwards, the air gets cooled, and rain is likely.

Exercise 29.—Fig. 24 shows another set of isobars also in

the form of closed curves. Which isobar is at the centre ? As you move outwards from the centre does the pressure increase or decrease ? Where is the pressure highest ?

Such a system of closed curves enclosing an area of high pressure is called an **anti-cyclone.** Which way do the winds blow—to or from the centre ? Is their direction clockwise or anti-clockwise ? Why should this be so ? Draw a diagram to show the barometric gradient along A B. Where were the winds strongest ? Compare the two gradients you have drawn and state which is the steepest. Are the winds of the cyclone or the anti-cyclone usually the strongest ?

In anti-cyclonic areas the air is drawn downwards from cold dry layers and gets warmed as it descends. Hence it generally takes up moisture instead of parting with it. In such cases there are few or no clouds, and the conditions are more permanent than in low. Fine weather then often lasts for weeks.

Exercise 30.—During the rest of the school year keep a record of the winds in the following form. On squared paper draw eight lines crossing each other and pointing respectively N., S., E., W., N.E., S.E., N.W., S.W. Every day at a given hour see in which direction the wind is blowing and fill in one of the squares along the appropriate line, beginning near the centre where the eight lines cross. If the sky is clear colour the square red ; if dull, blue ; and if rain is falling, black. Then note as the days go by,

(*a*) Which are the commonest winds.

(*b*) Which are the wettest winds.

(*c*) Which are the driest winds.

REVISION EXERCISES

1. Define isobar, cyclone, and anti-cyclone.
2. Draw a series of isobars showing the form of a typical cyclone and insert arrows showing the direction of the wind in different parts. O. S., 1899.
3. Write out all you have learned in this chapter about winds, cyclones, and anti-cyclones.

CHAPTER VIII

RAIN

THE sun shines upon the rivers, lakes and seas and changes much of the surface water into an invisible vapour which ascends into and is absorbed by the air. As the air ascends, the pressure upon it decreases, and so it expands. As the air expands, it cools, and the vapour which it contains is condensed to a visible form and falls as **rain.**

The amount of the rainfall is measured by a **rain-gauge**[1] (Fig. 25). It is measured in inches. You will see sometimes in a newspaper that there has somewhere been a fall of rain of 1 inch. What does this mean ? It means that if all the rain that fell had stayed on the ground, so that none had been lost by evaporation or drainage, or through other causes, then the ground would have been covered uniformly with water to the depth of 1 inch.

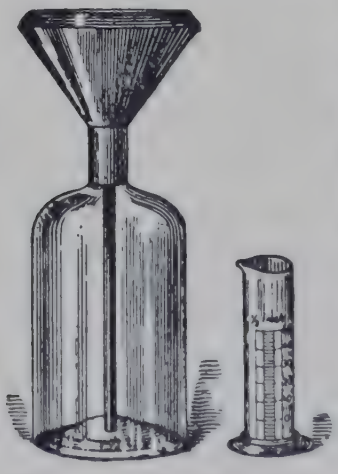


FIG. 25.—RAIN-GAUGE.

A rain-gauge consists of a funnel to catch the rain and a vessel in which to receive it.[1] A measuring jar is provided, and it is so marked that the amount of the rainfall can be read directly. A full glass would represent a rainfall of half an inch. The divisions on the glass represent tenths and hundredths of an inch of rainfall. In future, measure the rainfall and record your results on the Meteorological Register. Learn to represent the results diagrammatically as shown in Fig. 26.

The thermometer and the barometer change continuously, so that we can represent their variations by a continuous line. But rainfall is not continuous and must not be represented by a continuous line. Instead of drawing a line

[1] Messrs. G. Philip & Son supply a serviceable rain-gauge. See p. 161.

we draw little shaded rectangles. You may regard them as a series of pictures of measuring glasses holding the rain-water (Fig. 26). The heights of the shaded rectangles

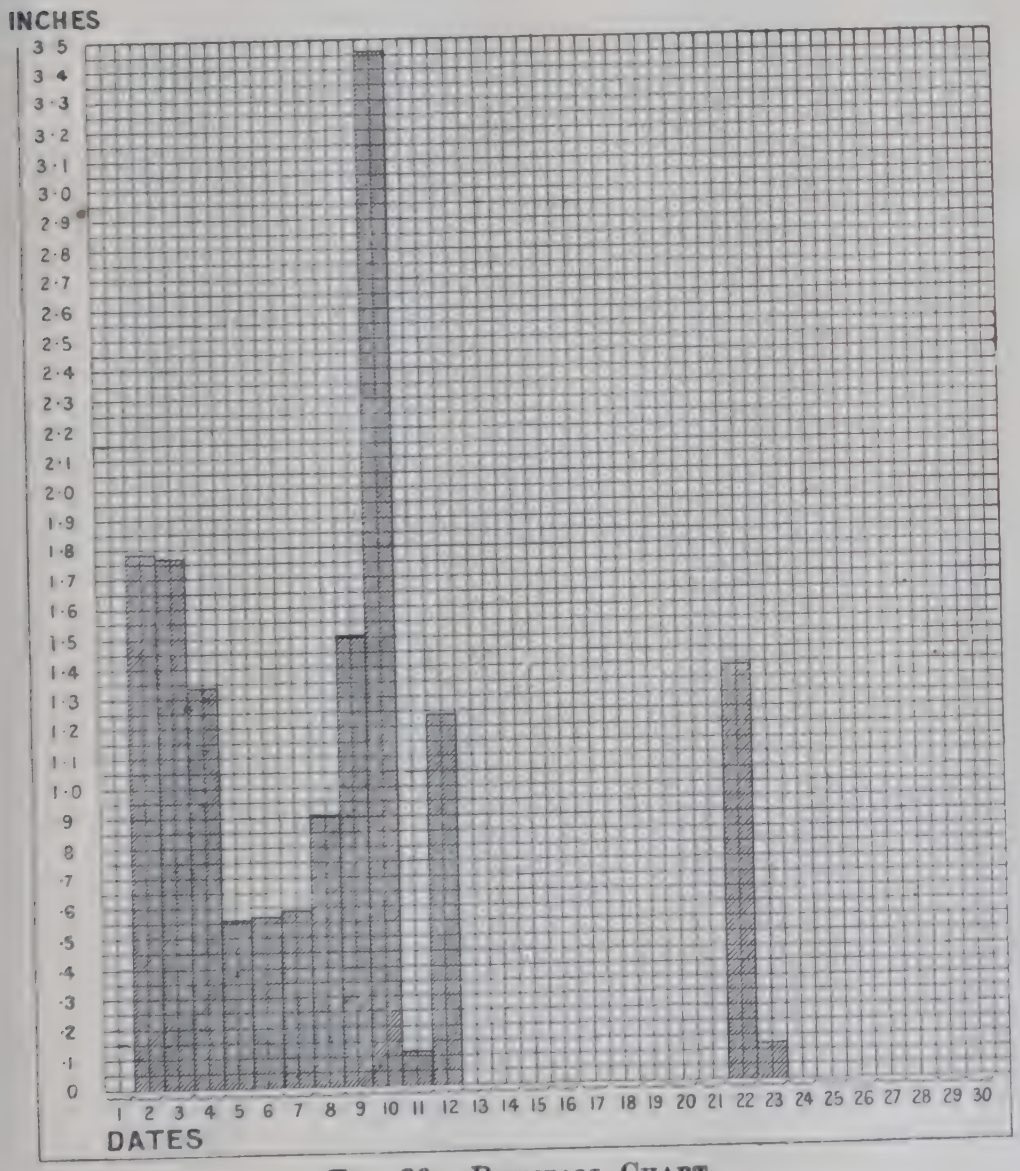


FIG. 26.—RAINFALL CHART.

show the amount of the rainfall. The given diagram shows the rainfall at Lugano for the month of November, 1906 The facts represented in the diagram are recorded in the following tabular statement

Day.	Rainfall in Inches.	Day.	Rainfall in Inches.
1	0·00	16	0·00
2	1·78	17	0·00
3	1·77	18	0·00
4	1·34	19	0·00
5	0·55	20	0·00
6	0·56	21	0·00
7	0·59	22	1·38
8	0·91	23	0·12
9	1·51	24	0·00
10	3·47	25	0·00
11	0·12	26	0·00
12	1·24	27	0·00
13	0·00	28	0·00
14	0·00	29	0·00
15	0·00	30	0·00

Exercise 31.—The rainfall at Aberdeen for twelve months was as follows —

January	2·13 in.	July	3·05 in.
February	2·41 „	August	2·58 „
March	2·68 „	September	2·36 „
April	1·86 „	October	2·78 „
May	2·20 „	November	3·04 „
June	1·63 „	December	2·96 „

What was the total quantity of rain that fell at Aberdeen ? What was the average monthly rainfall ?

Exercise 32.—In the following table we have the rainfall at Teddington for the month of January for each year from 1893–1902.

Year.	Rainfall in Inches.	Year.	Rainfall in Inches.
1893	2·05	1898	0·67
1894	2·48	1899	3·23
1895	2·82	1900	3·20
1896	0·81	1901	1·27
1897	2·19	1902	0·87

Calculate the mean monthly rainfall at Teddington for January for the ten years 1893–1902.

If we add together the total amount of rainfall at a place for, say, ten years, and then divide the sum by ten, we get the **mean annual rainfall**. The mean annual rainfall for a period of ten years for a number of places in the British Isles is given below.[1]

Ballachulish (Argyll-shire)	84 in.	Appleby	33 in.
Fort William	80 „	Belfast	33 „
Greenock	60 „	Armagh	32 „
Keswick	60 „	Alnwick	31 „
Valentia	56 „	Limerick	31 „
Buxton	49 „	Aberdeen	31 „
Carmarthen	49 „	Dundalk	30 „
Stornoway	48 „	Lichfield	30 „
Haverfordwest	47 „	Liverpool	30 „
Rothesay	47 „	Salisbury	30 „
Falmouth	44 „	Southampton	29 „
Tuam (Galway)	44 „	Wick	29 „
Swansea	42 „	Brighton	28 „
Sligo	40 „	Chester	28 „
Londonderry	40 „	Dover	28 „
Dunkeld	39 „	Dundee	28 „
Abergavenny	38 „	Newcastle	28 „
Donaghadee	38 „	St. Andrews	28 „
Tipperary	38 „	Birmingham	27 „
Waterford	38 „	Dublin	27 „
Glasgow	36 „	Scarborough	27 „
Kelso	36 „	Framlingham (Suffolk)	26 „
Mullingar	35 „	Haddington	26 „
Wells (Kent)	35 „	Yarmouth	25 „
Ardrossan	34 „	Oxford	25 „
Clifton (Gloucs.)	34 „	Reading	25 „
Holyhead	34 „	York	25 „
Plymouth	34 „	Edinburgh	24 „
Shaftesbury (Dorset)	34 „	Cambridge	22 „
		Shoeburyness (Essex)	18 „

We can draw lines upon a map connecting places with the same mean rainfall similar to those we have learned to draw connecting places with the same mean temperature or pressure. In the case of rain these are called **isohyets**.

Exercise 33.—On an outline map of the British Isles draw the isohyets for 34 inches. On the same map mark and name all the places with a mean annual rainfall under 30 inches and

[1] It is usual to take 35 years.

all those with a mean annual rainfall over 40 inches. On which coasts do we find (*a*) the lowest, (*b*) the highest rainfall ?

Exercise 34.—Fig. 27 gives the mean annual rainfall for the British Isles. Do the facts there represented confirm your previous observations ? Draw a section across the

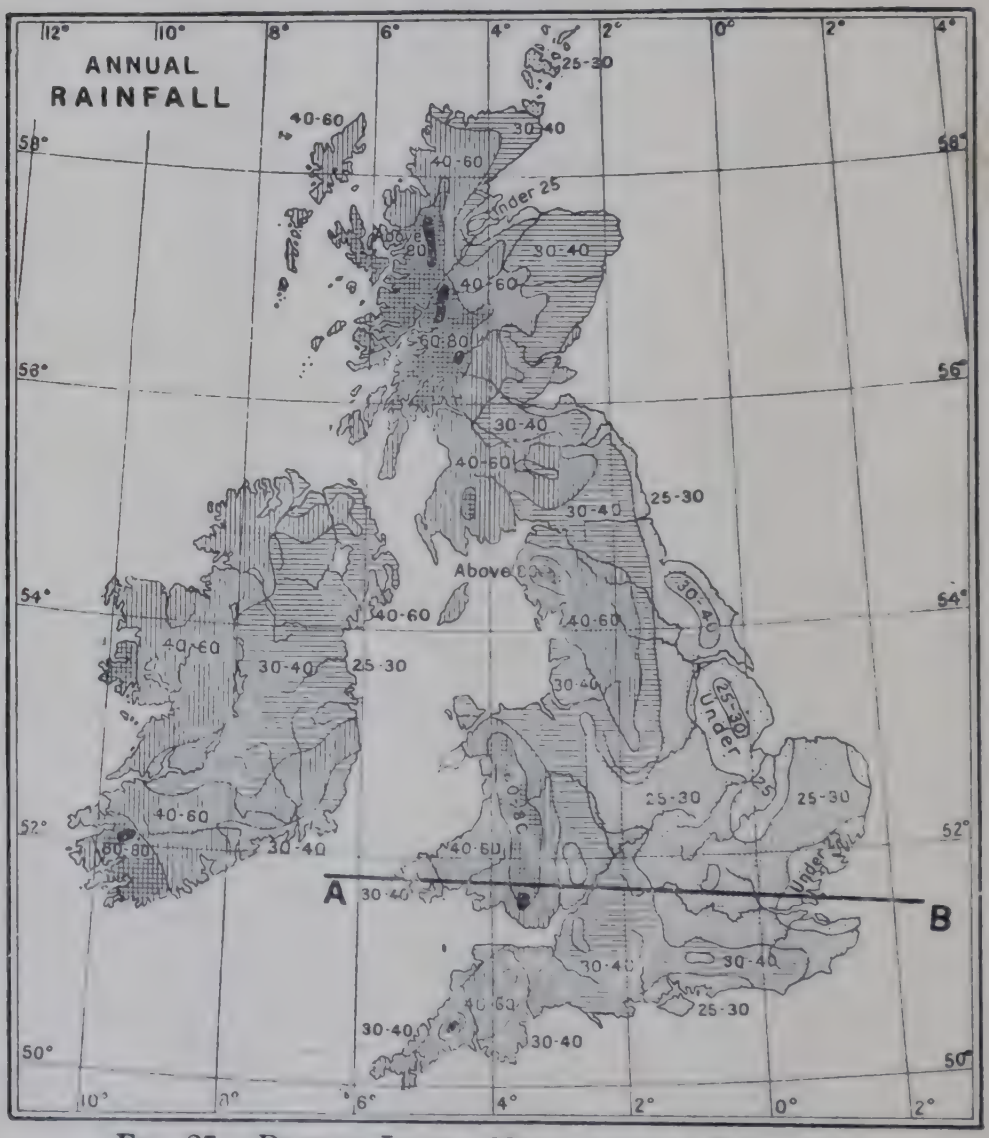


FIG. 27.—BRITISH ISLES: MEAN ANNUAL RAINFALL.

map, along the line A B, to show how the rainfall varies as we pass across the country from Wales to England. (Use the same method as adopted for showing the barometric gradients.)

Exercise 35.—Compare Fig. 27 with the physical map of

the British Isles in your atlas. Which coast has the most rain? Where are there most mountains? Which coast is driest? Where are there fewest mountains?

The chief winds in these islands are south-west winds. They blow on an average two days out of three. Do they blow over land or water? Are they wet or dry? Can you see any connection between prevailing winds, mountains and rainfall?

One of the wettest places in England is Seathwaite, whose mean annual rainfall is about 172 inches. Account for this fact. Do our east winds blow mostly over land or water? Are they wet or dry winds? Which is the driest place in the list given to you on p. 41? Is there any connection between rainfall and wind on the east coast?

We may summarize the knowledge gained so far in these lessons as follows :—

i. **Mountains influence Rainfall.**—When the clouds drift towards a mountain range they are forced up over the top of it and cooled. The moisture becomes condensed and falls as rain. The windward side of the range is consequently wetter than the leeward side. This partly explains how it is that our west coasts are wetter than our east coasts.

ii. **Winds influence Rainfall.**—Our most common wind is that from the south-west. These winds come to us laden with moisture from the broad Atlantic. They drive against the western hills and mountains, are cooled, and deposit rain.

"In passing across England from east to west it is found that, as a rule, the rainfall increases. Thus in the basin of the Thames, the fall varies from about 24 inches in the eastern part to between 30 and 40 inches among the western hills in which the Thames takes its rise. Looking at the entire basin of the Thames, it may be said that the average rainfall is about 26 inches. Now, the area of the basin comprises upwards of 6,000 square miles. Suppose, then, that we measured out a square space a mile in length on each side, and built upon this base a four-sided tower, $2\frac{1}{2}$ miles in height, which we completely filled with fresh water; this enormous column would represent the quantity of water

which falls upon the Thames basin in the course of twelve months. And it should be borne in mind that every drop of this water has at some time existed in the atmosphere as an invisible vapour. In one sense, therefore, it may be truly said that the Thames has its source in the air" (*Physiography*, Huxley).

Exercise 36.—Re-write this paragraph in your notebook

FIG. 28.—EUROPE: MEAN ANNUAL RAINFALL.

making the necessary alterations in figures, etc., so as to give a description of the river basin in which your school lies.

Exercise 37.—Examine next the map (Fig 28) which shows the rainfall in Europe. The same results will be noticed as in the British Isles. There is more rain on the west than the east.

Why is Sweden drier than Norway? Why is the eastern side of Italy drier than the western? Why is the interior of the Balkan peninsula dry? Why is the south of the Balkan peninsula warmer and milder than the north?

The wettest part of France is Brittany. Why? Would you say that Russia was likely to have a dry or a damp climate? Why? The Harz Mountains is the wettest district in Germany. Why? The plains of Hungary suffer from drought. Why?

Which places in Europe have a mean annual rainfall over 80 inches?

What is the mean annual rainfall of Leningrad, Corsica, Vienna, Stockholm, Moscow, Paris, Madrid, Rome?

REVISION EXERCISES.

1. Give some account of the causes of rainfall, and describe a special case where the conditions are calculated to produce an excessive rainfall. C. J., 1900.

2. How is rainfall measured? Where does most rain fall in the British Isles? Where least? Explain as fully as you can. L. J. S., 1904.

3. Compared with central England, the climate of Cornwall is noted for (*a*) cool summers and mild winters, and (*b*) abundant rainfall. How do you account for these facts? O. P., 1906.

4. Contrast the climate of the east of England with that of the west of England and explain the reason of the difference. C. S., 1904.

5. What are the chief causes of the difference in climate of Lisbon and Moscow? C. S., 1890.

6. In winter it is warmer in the west than in the east of England, but in summer it is warmer in the east than in the west. It is usually wetter in the west than in the east. How can you explain these facts? L. J. S., 1905.

7. How does the average rainfall differ in various parts of the British Isles, and to what causes are these differences to be assigned? O. J., 1903.

8. From the figures supplied below discuss the nature of the climate at each of the stations, A, B, C, D, and point out in what part of the world it might be found.

—	Temperature (Fahr.).				Rainfall, Inches.				
	Jan.	April.	July.	Oct.	Dec. to Feb.	Mar. to May.	June to Aug.	Sept. to Nov.	Year.
A	41·2	47·5	60·0	51·8	13·1	9·6	13·9	18·2	54·8
B	22·0	38·2	64·2	48·0	16·1	13·6	11·1	14·0	54·8
C	77·5	79·3	78·3	79·5	35·7	16·0	9·2	12·0	72·9
D	73·0	82·5	80·9	81·0	0·2	0·5	63·0	13·1	76·8
London	37·9	48·9	64·4	50·1	5·4	5·4	6·5	7·2	24·5

N.B.—As an example of the way in which such questions should be treated we append a question from the Second Division Civil Service Examination of September, 1910, with a fully worked out solution.

The following figures give the mean monthly temperature and rainfall for two places A and B. State to what part of the world each may belong and give reasons.

	A. (altitude 750 ft.)		B. (under 100 ft.)	
	Temperature.	Rainfall.	Temperature.	Rainfall.
	°F.	Inches.	°F.	Inches.
January	—3·8	0·83	52·2	4·1
February	—1·5	0·93	52·5	3·1
March	14·9	1·07	54·9	3·7
April	38·9	1·55	59·2	2·6
May	51·7	2·31	65·0	1·1
June	62·0	3·43	71·2	0·5
July	65·8	3·03	76·5	0·2
August	62·7	2·55	77·0	0·6
September	53·7	2·11	73·8	2·0
October	40·9	1·61	67·1	3·8
November	21·0	1·00	59·4	4·0
December	5·4	0·92	54·0	3·8

A. As January (—3·8°) is colder than July (65·8°) the place A is evidently in the northern hemisphere: as there is a great range of temperature between summer and winter it must be in a large land mass and near the centre of it. The rainfall is only a little over 20 inches: this supports the idea that it is in the centre of a land mass. The maximum rainfall is in summer, i.e. the land is a monsoon land, while the summer temperature is not very great—just under 66°. This points to the north centre of North America rather than Asia. The position of A is probably not far removed from that of Winnipeg: the altitude, 750 feet, supports this view.

B. Again, January is colder than July, so we are again dealing with a place in the northern hemisphere. August is warmer than any month that precedes it, so B is north of the tropic. There is, however, a comparatively small *range* of temperature, so we should expect B to be placed beside a large expanse of water. Most of the rain falls in winter, so that the climate is what is called Mediterranean. As it is rather hot in summer and 77° in August, the southern shore of the Mediterranean is suggested. The rainfall —30 inches per annum—is too great for the coasts of Tripoli or Egypt, so it is probable that the climatic conditions given will be satisfied in some part of the Barbary States. The altitude is under 100 feet: this agrees with the fact that B is near the coast.

CHAPTER IX

THE WEATHER REPORT

EVERY day the Meteorological Office receives from a large number of stations (Fig. 29) reports as to the height of the barometer, the direction and strength of the wind and other

particulars at these stations. From these reports maps and diagrams are made and the probable character of the weather for 12 or 24 hours or even longer is forecasted.

FIG. 29.—METEOROLOGICAL STATIONS.

Three sections of the Daily Weather Report are issued each day: the British Section, the International Section and the Upper Air Section. These can be obtained from the Director, Meteorological Office, Air Ministry, Adastral House

Kingsway, London, W.C. 2. The cost of a copy of one section, post free, daily for a year is 25*s.*, and for two or three sections 50*s.* The corresponding charges for a month are 2*s.* 6*d.* and 5*s.* For class use copies of current Daily Weather Reports for a particular day or succession of days can be specially printed and supplied at the rate of 7*d.* for ten sheets, postage extra, if the order is received not later than the first post on the day of issue. Sets of free copies of the British and International Sections for about 14 consecutive days are available for presentation for the cost of postage, usually only 9*d.*

Exercise 38.—Examine page 1 of the British Section of the Report. The upper portion is divided into twenty-nine columns. In the first is the list of stations in Britain from which reports are received. In the other columns are found the observations for "1300 G.M.T." (i.e., 1 p.m., Greenwich Mean Time) and "1800 G.M.T." for the day before. On page 4 is given corresponding information for 0100 G.M.T. and for 0700 G.M.T. of the day on which the report is issued. Usually it is the information for 0700 G.M.T. (or 7 a.m.) which is the most interesting, because it is the last issued, and it will be sufficient if we examine it. We have in the first six columns (*a*) the height of the barometer at M.S.L. (i.e., reduced to what it would have been at mean sea-level, (*b*) the change in the barometer in the last three hours, (*c*) the direction of the wind, (*d*) the force of the wind, (*e*) the weather, (*f*) the temperature.

The barometer is said to be given in "mb." This stands for *millibars*. Most barometers show what is called the height of the barometer in inches of mercury, but for the purposes of the Weather Report it is more convenient, as well as more correct, to work with units of *pressure*—a millibar is the unit of pressure. A reading in inches may easily and accurately be turned into millibars by the use of conversion tables, but any reading in inches may be found quite sufficiently accurately in millibars by the use of the scale between pages 2 and 3 in the Weather Report.

The force of the wind is measured in the Beaufort Scale given on the next page; the titles of the different winds being added, and means by which the force of the wind may be estimated on land.

THE BEAUFORT SCALE OF WIND FORCE.

Beaufort Number.	Admiral Beaufort's General Description of Wind.	Specification for use on Land, based on observations made at Land Stations.	Limits of Mean Velocities. Statute Miles per hour.
0	Calm .. .	Calm; smoke rises vertically	Less than 1
1	Light Air ..	Direction of wind shown by smoke drift	1—3
2	Slight breeze ..	Wind felt on face; leaves rustle	4—7
3	Gentle breeze ..	Leaves and small twigs in constant motion; wind extends light flag	8—12
4	Moderate Wind	Raises dust and loose paper; small branches are moved	13—18
5	Fresh Wind ..	Small trees in leaf begin to sway; crested wavelets on inland waters	19—24
6	Strong Wind ..	Large branches in motion; whistling heard in telegraph wires	25—31
7	High Wind ..	Whole trees in motion; inconvenience felt when walking against wind	32—38
8	Gale	Breaks twigs off trees; generally impedes progress	39—46
9	Strong gale ..	Slight structural damage occurs (chimney pots and slates removed)	47—54
10	Whole gale ..	Seldom experienced inland; trees uprooted ..	55—63
11	.. .. ..	Very rarely experienced; accompanied by widespread damage	64—75
12	Hurricane ..	.. ..	Above 75

Under the heading of "Weather" you will find a number of letters, e.g., b, o, r and c. What these mean will be found at the foot of page 1.

Exercise 39.—Take the station nearest where you live and say three others, and state the pressure, temperature, direction of wind, force of wind and character of the weather. Which place had (*a*) the highest pressure, (*b*) the lowest pressure?

Exercise 40.—Turn to page 3. Here the isobars are drawn on a large map which shows more than the British Isles. On the map plot the height of the barometer and the direction of the wind at each of the four places you have chosen. Notice that each reading fits into its place as shown by the isobars. What do you notice about the direction of the wind?

The upper left-hand portion of page 2 gives a summary of the weather, temperature, rainfall and sunshine for the past 24 hours.

Exercise 41.—Draw a map of the British Isles. On it plot the number of hours of sunshine as given in the last column on page 2. Shade the districts which have most or least sunshine, according as is most convenient. Is this what you might have expected from inspection of the map on page 3?

At the top of page 2 there is a little map headed *isallobars*. This has been constructed from the column on page 4 which gives the change in the barometer in 3 hours. It shows where the barometer is rising or falling most quickly, i.e., where changes are most likely to take place.

Exercise 42.—On the table on page 4 or the map on page 3 note what is the symbol for the weather at 7 a.m. at the place nearest your home. Judging by the isallobar map,

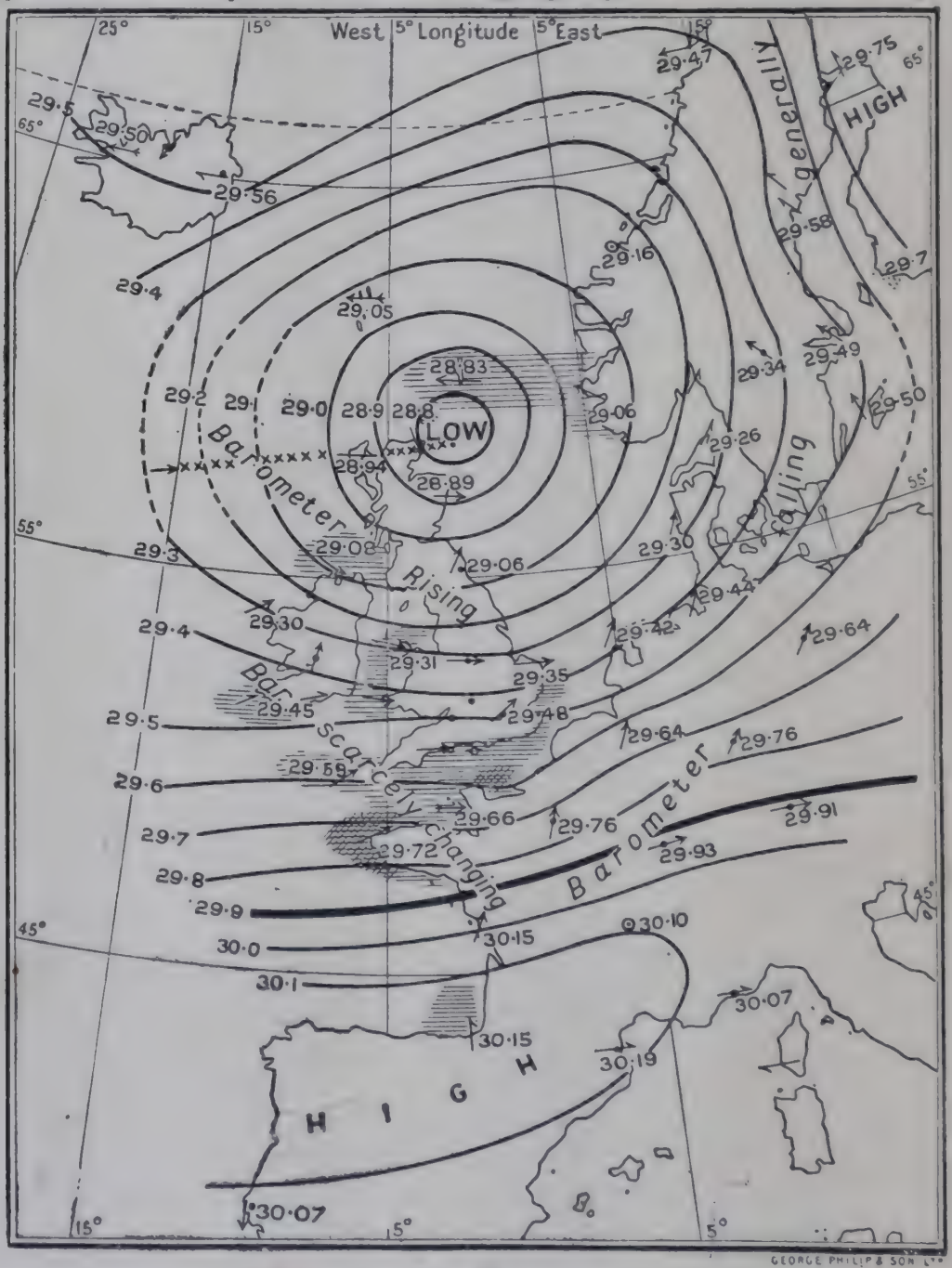


FIG. 30A.

what pressure changes are likely to take place and what kind of weather changes would you expect? Compare this with the forecast for your district at the foot of page 2. If you are studying the map shortly after issue notice whether these changes you expect are actually taking place.

The International Section gives information for Continental stations of the same kind as that given in the British Section for the British Isles. Some of the information is utilized in

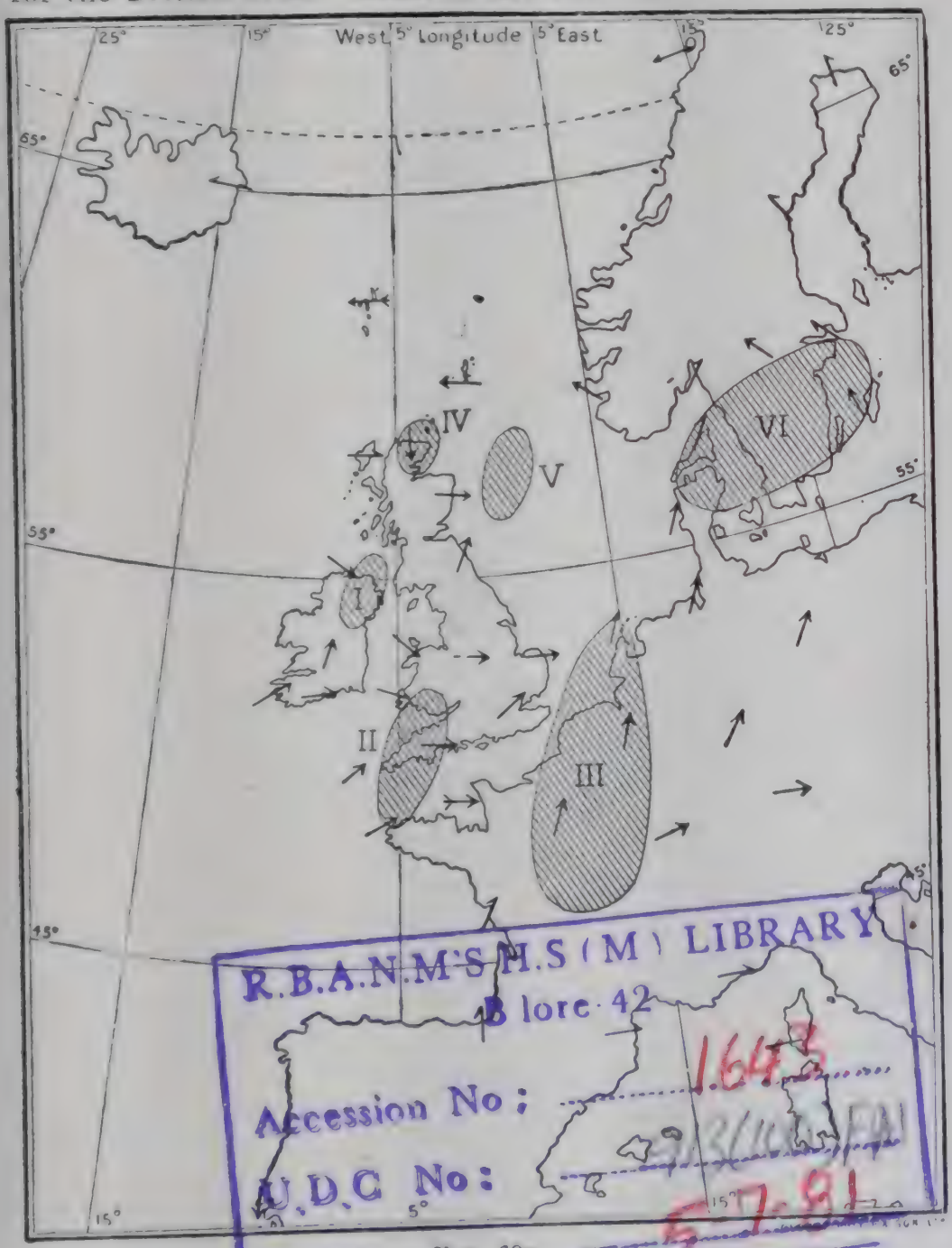


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FIG. 30B.

the construction of the map in the British Section. One difference is that information is given, on page 1, for only twice a day, usually 7h. and 18h. (i.e., 7 a.m. and 6 p.m., G.M.T.). On pages 2 and 3 are given two large maps and two

small ones. The two large maps show all Western and Central Europe ; isotherms are drawn on them.

Exercise 43.—Notice which is the (*a*) warmest, (*b*) coldest portion of the area shown on the map on page 3. What do you notice with regard to the winds in each of these regions? Can you relate the temperature to the direction of the wind currents?

Exercise 44.—Notice the arrows which show both the direction and the strength of the winds. Find a portion of the map where the isobars are close together; how many barbs have the arrows there? What is the strength of the wind? Find a portion of the map where the isobars are far apart; how many barbs have the arrows? What is the strength of the wind?

The Upper Air Supplement gives the direction, velocity and temperature of the wind at certain heights over a few stations, together with the kind and amount of cloud.

Exercise 45.—Look at page 2. Note (*a*) the figures given in the upper part of the sheet for the speed of winds at different places, and say what you notice about the speed of the wind at 2000, 3000, 4000 feet and above as compared with the speed of the wind on the surface ; (*b*) the figures given at the bottom of the sheet and say what you notice about the temperature at 2000, 3000, 4000 feet and above as compared with the temperature at sea-level.

Read the various notes given on the different pages of the Weather Reports and connect them with the information on the maps and diagrams.

You have now to try your hand at describing the weather from similar charts. The chief things to remember are :—

(1) Wind : (i) direction : the wind arrows fly with the isobars, slightly curving to the centre of the low pressure :—

(ii) Strength : this is shown by barbs and feathers to the arrows : the wind strength is greatest if the isobars are close together. Toward the central area of an anti-cyclone it tends to be calm.

(iii) Temperature and humidity.

(*a*) Winds which come a long distance from north or north-east are cold and dry.

(*b*) Winds from the west are damp and warm in winter, damp and cool in summer. Note that winds which originally came from the west may have been turned round to follow the isobars. They still tend to retain their character.

(*c*) Winds which come a long distance from east or south-east are dry and hot in summer, dry and cold in winter.

(*d*) Winds coming from the south may be west winds turned round or east winds turned round.

(*e*) The central area of an anti-cyclone tends to be bright and warm in summer, but sometimes hazy. in winter the central area of an anti-cyclone is cold and dry but often foggy.

(2) Rain : (*a*) The damp winds of (iii) (*b*) usually bring rain.

(*b*) If two sets of winds are converging, one or both must be rising and rain must be falling.

(*c*) If two sets of winds are diverging from an area, air must be descending there and it is probably dry.

As an example consider the following exercise and its solution :—

Write a brief description of the weather in the Shetlands, the English Channel, the south of France, the Baltic Sea, as indicated in the figure (Fig. 30A). State where the wind is strongest and where it is calm. Shade the area in which you would expect to find rain. L. J. S., 1907.

Shetland.—The isobars are rather close together and the arrow shown is double-headed, so we know that there is a fair breeze and that the sea is rather rough in consequence. The wind is from the east. It will depend on whether the map is for a day in summer or for a day in the winter, whether the weather tends to be hot or cold ; but the Shetlands are small islands in the open sea rather far north, so that the temperature will be modified in any case and probably cool ; rain is possible.

English Channel.—The isobars are rather close together : the arrows are double-headed or even feathered, and the sea is rough, so there is a gale. There is little change in the barometer, so the isobars have held their present direction for some time ; the winds must have come from a considerable distance to the west ; they are therefore

damp. It will depend on whether the map is for summer or for winter whether they will be classed as cool or warm ; they will not be cold. On the west of the Channel they seem to be rather converging, so that rain will be falling. On the east of the Channel the west winds seem to be running straight into winds from the south : there is therefore likely to be rain southward and eastward of the Strait of Dover.

FIG. 31.—EUROPE: WIND DIRECTION.

South of France.—The isobars are far apart : the arrows are single-headed, the winds are therefore light ; they are coming out of a high pressure area and tending to diverge ; the sky is therefore likely to be clear or with a few clouds only. The temperature is likely to be warm but not hot, even if this is a summer map .

Baltic.—Over the Baltic the winds are from the south: the arrows in the north have one barb only and are light. Those in the south have two barbs and are stronger. Thus those in the south are overtaking those in the north. Some air is probably rising and being cooled. If this is taken

FIG. 32.—WESTERN EUROPE: BAROMETRIC HEIGHTS.

with the fact that the winds are moving from the south, which is probably warmer than the north, it is likely that rain may be falling or at any rate that there are clouds.

Rain.—The regions where rain may be falling are shaded. In those numbered i. ii. iv. v. (Fig. 30B) there is a

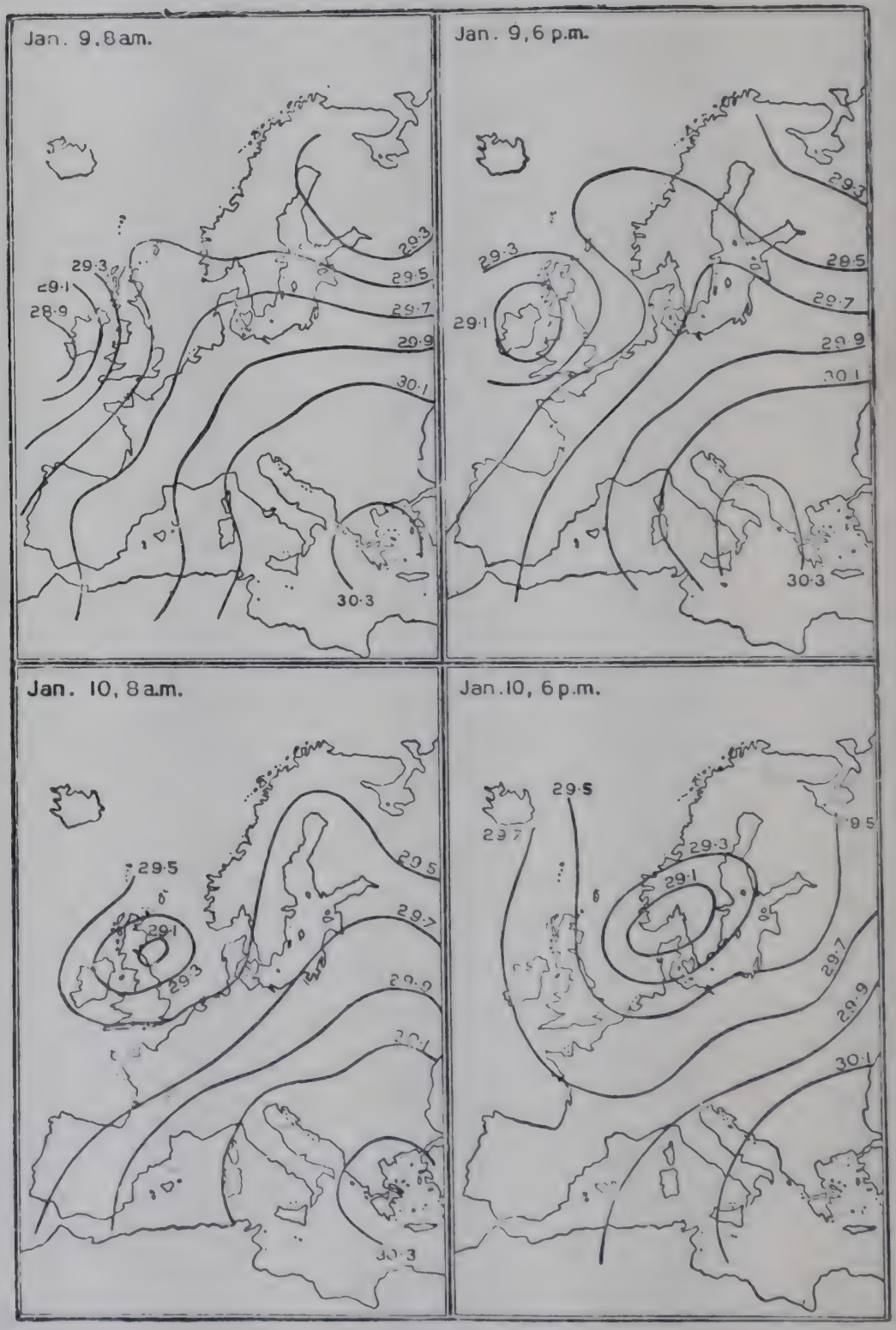

Jan. 9, 8 a.m.
29·3
29·1
28·9
29·3
29·5
29·7
29·9
30·1
30·3
Jan. 9, 6 p.m.
29·3
29·1
29·5
29·7
29·9
30·1
30·3
Jan. 10, 8 a.m.
29·5
29·1
29·3
29·5
29·7
29·9
30·1
30·3
Jan. 10, 6 p.m.
29·5
29·7
29·3
29·1
29·7
29·9
30·1

FIG. 33.

marked convergence of winds, so that some air must be rising. The region marked iii. is where westerly winds are apparently pushing under south winds and raising them. In the region marked vi. it is possible, as stated above, that rain is falling, but the observations are too scattered to warrant any very definite conclusions. Rain might be falling in the north-west of Scotland as the west wind rose over the north Highlands; but winds are diverging there considerably so that it is rather more probable that there is no rain there.

REVISION EXERCISES

1. Draw or write a brief description of a weather map of a low pressure system or cyclone, the centre of which is at London where there is a pressure of 29 inches. L. J. S., 1906.

2. On the accompanying map of Europe (Fig. 31) the direction of the wind is indicated by various arrows. Draw three or four isobars and write the word Low where the pressure is lowest. Describe the general character of the weather in different parts of the area represented. C. S., 1905.

3. On the morning of a day in winter the barometer was observed at a number of points in western Europe. These heights, corrected for temperature and reduced to sea-level, are shown in Fig. 32. Draw isobars upon the map and indicate the probable direction of the winds, and give a general account of the weather which probably prevailed at the time of the observations. C. S., 1903.

4. The maps supplied in Fig. 33 show the distribution of barometric pressure over western Europe on the dates and at the hours specified. Describe the changes in the weather experienced in London during the period. C. S., 1906.

5. Describe clearly what is meant by an anti-cyclone. When there is an anti-cyclone over Denmark, what is the probable character of the weather in England? C. S., 1902.

CHAPTER X

THE CLIMATE OF YOUR OWN NEIGHBOURHOOD

At the end of the year, when your records are complete, answer the following questions. The values of mean annual temperature, rainfall, etc., can often be obtained from the different volumes of Methuen's *Little Guides*, and other similar guides to the different English counties.

1. What is the latitude of your school?

2. What is the mean annual temperature for the given year in the school playground?

3. What is the average mean annual temperature for your town?

4. Are 2 and 3 what you might expect from the latitude ?

5. How far is your own town from the sea ?

6. What is its annual range of temperature ?

7. Compare this with the annual range of temperature at other towns in the same latitude in other parts of the world.

8. Mention any special circumstances that affect the temperature of your own neighbourhood, such as the presences of hills, swamps, sea, etc.

9. What is the mean annual pressure as recorded by the school barometer ? What is the mean monthly pressure for each month of the year ?

10. Is your school in a wet or a dry district ? What is its mean annual rainfall ? Account for the observed facts.

PART II

THE WORLD AS A GLOBE

CHAPTER XI

THE SHAPE OF THE EARTH

Exercise 46.—Place a globe on a table in the middle of the class-room. Examine it carefully by touching it at various points with a flat piece of thin wood (e.g. the lid of a cigar box). Is the globe flat anywhere ?

Now this globe is supposed to represent the world on which we live. The ancients thought that the world was flat, and this is still the belief of many savage or semi-civilized people in distant parts of the globe.

Exercise 47.—Take a toy soldier. Put him in any part of the globe on one of the lines that are drawn thereon. Move the figure along the line, always keeping his face in the same direction. Presently he will arrive at the place from which he started.

Now if we imagine a man travelling round the earth in the same way, that is, going on always in the same direction, he would, after a certain length of time, arrive at the place from which he set out. Hence we believe that the world is round. As a matter of fact men had to believe that the world was round before they made any attempt to sail round it. Since the first journey was made men have sailed round the earth in many directions.

Exercise 48.—Take a number of objects such as a penny, a ball, a cone, a cylinder, and an egg. In a darkened or semi-darkened room hold each of these objects in turn between a candle or other source of light and a sheet of paper. Each object in some position or other will throw a round

shadow, but the ball is the only one that will throw a round shadow in all directions.

From time to time the shadow of the earth is thrown upon the moon. The edge of this shadow is always part of a circle, and as the only body that can, in all positions, throw a circular shadow is a sphere, we conclude that the earth is a sphere.

Exercise 49.—If you are ever at the seaside watch a steamer going from the shore. The hull disappears first and the tops of the masts last. Now the hull is much larger than the tops of the masts, and, if the world were flat, the hull would remain in sight much longer than the smaller masts.

We have many other reasons for believing that the world is spherical, but these you can hardly find out by experimenting for yourself.

Exercise 50.—Take an india-rubber ball, and pass a knitting needle through it, so that the needle passes through the centre of the ball. For the moment, imagine that this is a model of the earth and that the knitting needle is the **axis** of the earth. The points where the needle projects are called the **Poles.** With a piece of chalk draw a line round the ball half-way between the poles. This line is the **Equator.** Now draw another chalk line passing round the ball and through the two poles. How many such circles could you draw passing through the poles and right round the ball? Such circles are called **great circles.** Measure the two circles you have drawn with a piece of string. You will find that they are equal in length.

But if you were to measure the distance round the world in this way the circumferences of the two circles would not be equal. The distance round the world when you pass through the poles is 42 miles less than when you go round the earth along the Equator. In the same way if you measure the distance through the world from pole to pole, and also the distance through the centre of the earth from a point on the Equator to another point on the Equator directly opposite to it, you will find that the first distance is 26 miles shorter than the second. The polar diameter is 7,900 miles long, and the Equatorial diameter is 7,926 miles long. It is evident that the world

is flattened a little at the poles and bulged a little at the Equator. Such a shape as this is called an **oblate spheroid**, that is, a flattened sphere-like body. The distance round the world is about 25,000 miles. The distance through it is about 8,000 miles (Fig. 34).

In Fig. 35 you have a sketch of an apparatus for making two circles of flat wire revolve very rapidly. When the

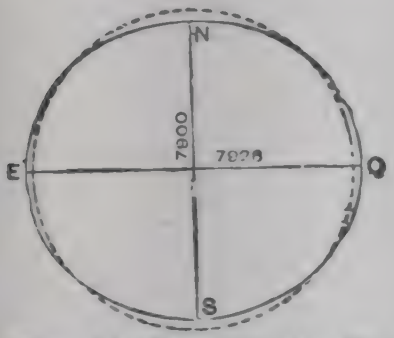


FIG. 34—SPHEROIDAL FORM OF THE EARTH.

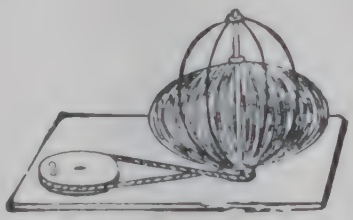


FIG. 35.—EXPERIMENT TO ILLUSTRATE THE PRODUCTION OF A SPHEROIDAL FORM BY ROTATION.

circles are rapidly revolved they appear to assume the shape shown by the shaded figure. It is believed that ages and ages ago the earth was a mass of semi-fluid material which was revolving in space. While in this condition, as it revolved, it would, like our wire circles, have a tendency to slightly flatten at the poles and bulge at the Equator.

CHAPTER XII

LATITUDE AND LONGITUDE

Exercise 51.—Take a piece of squared paper and on it draw two lines at right angles, crossing at a point O. Call the vertical line N O S, and the horizontal line W O E. It is required that you shall place a certain point A in the diagram you have just drawn. This point A lies on a line *half an inch* from the line N S. Draw two lines, one on each side of N O S, parallel to it, and at a distance of *half an inch* from it. The required point is somewhere on one of these two lines, for every point on each of the lines is *half an inch*

from N S. It is known that the point A is also *one inch* from the line W O E. Draw two lines parallel to E W, one on each side of it, and at a distance of *one inch* from it. A lies on one of these lines, and it also lies on one of the other two lines. It may therefore be in one of four positions. Mark with dots the four possible positions of A. Only one of these points is the required one. It is known that A lies *above* the line W O E. How many possible positions are there now? The point A lies to the *right* of N O S. How many points fulfil all the required conditions?

To define the position of a point we require to have two fixed lines, to know the distances of the point from these lines, and also to know on which side of each line the point lies. Positions above the line W O E are called north, and those below it south. Positions on the right-hand side of N O S are called east, and those on the left hand west.

Exercise 52.—Take another piece of squared paper. Rule on it two lines at right angles, and mark the positions of the following points :—

2 N 3 E ; 2 N 4 W,
3 S 3 E ; 2 S 4 W,
3 N 5 E ; 7 N 2 W,
4 S 3 E ; 4 S 4 W.

Find the position of 0 N, 2 E, and 0 N, 3 W. On what line do all places 0 N lie? All places 0 S? 0 E? 0 W?

The positions of places upon the earth's surface are found in a similar way, but the distances are measured in degrees.

Exercise 53.—Draw a circle. Through its centre O draw two diameters at right angles, N S, and E W. The angles at the centre of the circle, viz., N O W, S O E, S O W, N O E, are right angles. There are then four right angles at the centre of every circle. A right angle contains 90°, so that there are 360° in every circle. There are 90° from N to E, or from E to S, or from S to W, or from W to N.

Exercise 54.—Take your india-rubber ball, on which you have already drawn the Equator and one great circle through the poles. These two circles cut each other. Any point on

the Equator is 0° N., or 0° S. A point 90° N. is the North Pole. If it is 90° S. it is the South Pole. Can you get more than 90° N. or S. of the Equator ? Try on your ball. The great circle through the pole cuts the Equator in two points. There are 180° from the one point to the other. Suppose a point were 0° E., where would it be ? 0° W. ? 180° E. ? 180° W. ? Can you go more than 180° E. or W. of your great circle ?

Exercise 55.—Suppose there is a mass of lost treasure hidden in a certain spot in this world, and that you have to find it.

The spot is south of the Equator. It is 45° from the Equator. Find a point on your great circle half-way between the Equator and the South Pole. That is one point that is 45° S. Through this point draw a circle parallel to the Equator. *Every* point on that circle is 45° S. of the Equator. You do not want to sail all round the world. So you ask whether it is east or west of the great circle through the poles. It is east. How far east ? 60°.

Start at the point where the great circle cuts the Equator (60° = one-third of 180°). Measure off one-third of the semi-circle. The point you have found is on the Equator and 60° from the fixed line. Through this point draw a great circle passing through the poles. Now, if the spot where the buried treasure lies is both 45° S. and 60° E., where is it ?

Exercise 56.—Mark on your ball the following points, which you will find by following the above method.

30° N. 60° E., 30° N. 30° E.
60° S. 60° W., 60° S. 30° W.

Distance north or south of the Equator is called **latitude.** The circles drawn parallel to the Equator are called **parallels of latitude** (Fig. 36).

Distance east or west of a fixed line is called **longitude** The great circles drawn through the poles are called **meridians.** The one drawn through Greenwich is called the **First Meridian,** and it is from this line that we measure all longitude.

Exercise 57.—Examine a globe and answer the following questions.

Is London in north or south latitude ? Paris ? New York ? San Francisco ? Rio de Janeiro ? Cape Horn ? What is the latitude of the Equator ? of the North Pole ? of the South Pole ? Is Paris in east or west longitude ? Dublin ? Cape Town ? Cairo ? New Orleans ? Edinburgh ? Jamaica ?

The meridians are widest apart at the Equator. At the poles they intersect. One three hundred and sixtieth part of the Equator, that is, one degree of longitude at the Equator, measures 69 miles, but one degree of longitude at London measures only 43 miles.

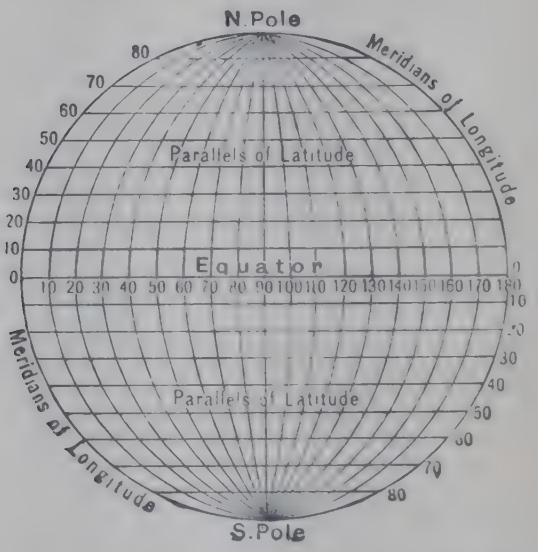


Fig. 36.—Latitude and Longitude.

If you stood at the North Pole and obeyed the command 'Right about ; turn," through how many degrees of longitude would you turn ?

Degrees are divided with smaller divisions, called **minutes**, and minutes are divided into **seconds**.

60 seconds make 1 minute.
60 minutes make 1 degree.
90 degrees make 1 right angle.

For these divisions, the following signs are generally employed : ″ for seconds, ′ for minutes, and ° for degrees.

There are about 25,000 statute miles in the circumference

of the world. There are 360° of latitude. About how many statute miles are contained in 1° of latitude ? As the world is not perfectly round the length of the degree of latitude varies as shown in the following table.

Latitude.	Length of 1°.
0°	68·70 statute miles
10°	68·72 ,,
20°	68·78 ,,
30°	68·87 ,,
40°	68·99 ,,
50°	69·11 ,,
60°	69·23 ,,
70°	69·32 ,,
80°	69·39 ,,
90°	69·41 ,,

One minute of latitude is a sea mile.

There are 360° in the Equator, and its length is about 25,000 statute miles. What is the length of a degree of longitude at the Equator ? A parallel of latitude farther north is shorter, but it still contains 360° of longitude, and as we have already pointed out, the degree of longitude becomes much shorter as we reach the poles. The following table shows some of the differences.

Latitude.	Length of 1° of Longitude.
0°	69·17 statute miles
10°	68·13 ,,
20°	65·03 ,,
30°	59·96 ,,
40°	53·06 ,,
50°	44·55 ,,
60°	34·67 ,,
70°	23·73 ,,
80°	12·05 ,,
90°	0·00 ,,

Exercise 58.—Find on a map or a globe the following places from the data given. Enter the names and figures in a table as shown.

Latitude.	Longitude.	Place.
51° 30′ N.	0° 5′ W.	
37° 58′ N.	23° 45′ E.	
31° 12′ N.	29° 53′ E.	
34° 35′ S.	58° 21′ W.	
30° 2′ N.	31° 15′ E.	
10° 30′ N.	66° 54′ W.	
53° 23′ N.	6° 20′ W.	
55° 57′ N.	3° 11′ W.	
44° 39′ N.	63° 35′ W.	
23° 9′ N.	82° 22′ W.	
55° 59′ S.	67° 16′ W.	
15° 20′ N.	32° 42′ E.	
6° 26′ N.	3° 26′ E.	
12° 3′ S.	77° 6′ W.	
40° 25′ N.	3° 40′ W.	
17° 27′ N.	88° 12′ W.	

Exercise 59.—Find from the map the latitude and longitude to the nearest degree of the following places.

Paris.	Cape Sable.
Berlin.	Cape Race
Vienna.	Valparaiso
Algiers.	Quito.
Cape Town.	Chimborazo.

Exercise 60.—Find on the globe the latitude and longitude of the following places.

Rome.	Philadelphia.
Moscow.	Cape St. Roque.
Cape Verde.	Rio Janeiro.
Teneriffe.	New Orleans.
Ottawa.	Chicago.

Exercise 61.—What meridian line passes through Berwick-on-Tweed and Poole? Name in order from north to south the counties it crosses, and give the chief town of each.

Give similar particulars, in order from east to west, in the case of a straight line drawn between Wexford and Tralee. C. S., 1888.

Give approximately the parallels of latitude between which lie the basins of the Mississippi and the Nile respectively. C. S., 1889.

Exercise 62.—Name the countries and seas through which the meridian of Greenwich passes.

Exercise 63.—Give the longitude of the points where the Equator cuts the coastline of Africa and South America.

Exercise 64.—The following meridians pass through certain British possessions. Fill in the names of these possessions.

Meridian.	British Possession.
2° 7′ W.	
5° 21′ W.	
14° 30′ E.	
20° E.	
30° E.	
0°	
66° W.	
82° W.	
77° W.	
59° W.	

Exercise 65.—Name in order the countries, seas, and islands through which the Equator passes, beginning at the meridian of Greenwich and going eastward all round the world. Mention any towns situated on or near the Equator. C. S., 1894.

REVISION EXERCISES

1. A seafight is said to have occurred in a certain latitude N. and longitude W. Explain clearly how the information thus given fixes the spot. Give the latitude of (*a*) the Tropic of Capricorn, (*b*) the North Pole. If I travel due west from Greenwich until I have gone half-way round the world, in which longitude shall I be? C. J., 1893.

2. Cape Town is in latitude 36° 56′ S., longitude, 18° 28′ E. Explain fully what this means. O. J., 1893.

3. What is meant by latitude and longitude? How does the length of a degree of each vary in different parts of the world? C. J., 1906.

4. Explain why the length of a degree of latitude is nearly the same in all latitudes, while that of longitude diminishes as latitude increases. O. J., 1906.

5. State approximately the latitude of Adelaide, Victoria Nyanza, Madrid, Leningrad, San Francisco, Calcutta; and the longitude of Alexandria, Bordeaux, New Orleans, Madras, Yokohama.

CHAPTER XIII

DIRECTION

We ought now to get some idea of how to determine the four chief points of the compass, the four **cardinal points** as they are called, viz., north, south, east, and west.

In the following ways you may find these directions approximately.

Fig. 37.—Pole Star and Pointers

Exercise 66.—Stand facing the sun at 12 o'clock: you will then be looking south. North will be behind you; west will be on your right hand, and east on your left hand.

Exercise 67.—Put a pin upright on the centre of the dial of your watch so that its shadow falls midway between the position of the hour hand and 12 o'clock: the line joining xii and vi then points north and south.

Exercise 68.—Look out for the group of stars called the Plough. Notice the position of the two stars called the Pointers. Draw in imagination a line through them. At about 4½ times the distance between the two Pointers you will see a bright star. This is the North Polar Star, and it is practically over the North Pole. A person at the North Pole has the North Polar Star practically right over his head at all times of the year.

But it may be cloudy either by day or by night, and it may therefore be impossible to see either sun or moon. The north can then be found by means of a mariner's compass. This consists of a magnetized needle balanced on a point so that it can turn easily in any direction. Underneath it is a card marked with the points of the compass. Now the earth acts as a great magnet in such a way that wherever you may be, the north pole of the needle turns towards the North Pole of the earth.

Exercise 69.—Put the compass on a drawing-board in the middle of your class-room. Find the N., S., E., and W. points in the room.

Exercise 70.[1]—Place a stick upright in the ground in some convenient part of the school premises where it will be safe from disturbance. Measure and note carefully the height of the portion of the stick above the ground. The length of the shadow is to be observed every half-hour from 9 a.m. to 3 p.m. and the results written down in column II of a table similar to the following one :—

Time of Day.	Length of Shadow.	Altitude of the Sun.
9.0 a.m.		
9.30 „		
10.0 „		
10.30 „		
11.0 „		
11.30 „		
12.0 „		
12.30 p.m.		
1.0 „		
1.30 „		
2.0 „		
2.30 „		
3.0 „		

Perform the measurements before the day of the actual lesson.

If your stick is on asphalt, mark the ends of the shadows with chalk. If the stick is on the grass, mark the ends

[1] If the class-room window face south, this experiment can be done inside the room, using a pin and a drawing-board.

of the shadows with small pegs of wood so that at 3 o'clock you can go out and see the various positions taken by the shadows.

When was the shadow shortest? Suggest a reason for this. The direction in which the shadow falls when it is shortest is **due north.** The sun itself is at the same time **due south.** If the shadow line were then continued in both directions it would pass round the earth through the two poles. The line obtained in the way indicated above is called the **meridian** of the place where the observations were made. If you stand on the meridian with your face to the north, and draw a line at right angles to the line of the meridian, the line will point **due east** on the right hand, and **due west** on the left hand.

It is not really very easy to find the meridian in this way, because it is not always possible to tell exactly when the shadow is shortest. The following method will help you to find the meridian without having to find the position of the shortest shadow.

Exercise 71.—Join the points found in Exercise 70 so as to form a continuous curve. Take a piece of string and make a loop at one end. Slip this loop over the stick and bring it down to the level of the ground. With the stick as centre and any convenient radius draw a circle to cut the shadow curve A P Q D in two places P and Q. Join P Q and draw S N at right angles to P Q. S N is the true North and South line. It should pass through the foot of the stick. Does the shadow of the sun fall on this line at 12 o'clock?

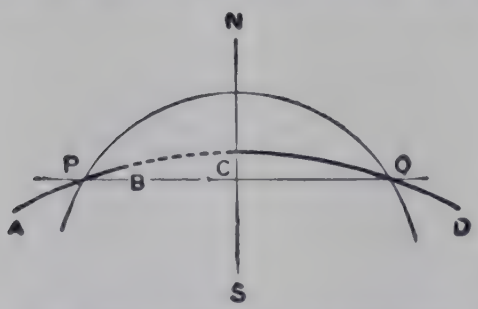


FIG. 38.—METHOD OF TRACING THE SUN'S SHADOW ON A CLOUDY DAY.

Exercise 72.—Measure at any convenient hour, every day for the next twelve months, the length of the shadow cast by the same stick in the same place. These lengths are to be plotted on squared paper and joined by a curve. Fasten up the paper in the class-room, and observe how the length of the shadow changes from day to day.

Exercise 73.—Notice the direction of the shadow cast by the pole at 12 o'clock Greenwich time. The shadow of the edge of the window pane on the floor will do very well. Continue your observations for some months. Does the shadow always lie in the same direction?

You will find that the sun is not usually exactly south at 12 o'clock. This is due to the fact that the sun does not keep exact time and to the fact that most places are not on the meridian of Greenwich. In order to find out when the sun is exactly south we have to take account of both these sources of error.

Exercise 74.—Notice in *Whitaker's Almanack* whether the sun is south at Greenwich before or after 12 o'clock: find the longitude of the school, and remembering that the sun takes four minutes to pass over 1 degree of longitude, find how many minutes elapse between the time when the sun is south at Greenwich and the time when it is south at your school. Add these two amounts together and so find the time at which you must observe the sun on any particular day. Note the direction of a shadow cast by a stick at this time: this direction lies exactly north and south.

Exercise 75.—On the first sunny day draw the true north and south line, as determined by the sun, either on the ground or on the floor of your class-room. Now place the centre of your compass on this line. You will find that the north and south line given by the compass does not agree with that given by the sun. There are then two north and south lines. There are two north poles. One of these, the one beneath the North Polar Star, is the geographical North Pole, while the other, the one to which the compass needle points, is the magnetic north pole.

Exercise 76.—Try to measure the angle between the two north and south lines. Is the magnetic meridian east or west of the geographical meridian?

The angle between the two meridians is called the **Magnetic declination.** In 1905 the declination at Greenwich was 16° 10·6′ W. If you wish to find the true north, you must know the declination at the place where your observations are made, for this declination is not everywhere the same. In 1904 the declination at Paris was 14° 30′ W.

If a man had drawn a line on a map, north and south by the compass, he would have had to draw another line 14° 30′ to the east of it to get the true north and south line. Again, the magnetic declination changes from year to year, so that it is necessary, even in the same place, to know the declination for each year if the true north and south is to be found by means of a compass.

The mean magnetic declination at Greenwich from 1917-1926 was as follows (to the nearest minute) :—

1917	14° 37′ W.	1922	13° 47′ W.
1918	14° 28′	1923	13° 36′
1919	14° 18′	1924	13° 23′
1920	14° 9′	1925	13° 10′
1921	13° 58′	1926	12° 56′

Exercise 77.—Examine the compass card. How many degrees are there between N. and E., between N. and N.E., between N. and S.E. ?

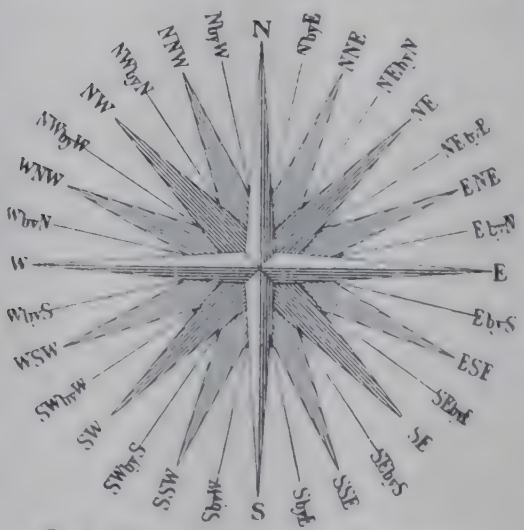


FIG. 39.—MARINER'S COMPASS.

A point is said to be, or to bear, north 15° west from another point B when the direction of A from B is obtained by looking towards the north and then turning westwards through an angle of 15°. Measurement in degrees is usually much more accurate than measurement by the 32 points of the compass. Directions are sometimes measured from the south point without any use of the three "other cardinal points." An object which is due west of another is said to have an Azimuth of 90° : one due north has an Azimuth of 180° : one due east has an Azimuth of 270°. The number of degrees is given by which the object is west of south.

REVISION EXERCISES

1. A man walks 1 mile due south from O to A, then successively 2¼ miles east south-east from A to B, 3½ north-east from B to C. 3½ miles due

west from C to D, and then finally straight from D to his starting point O. Draw a plan of his walk, taking 1 inch to represent 1 mile. Give the length of DO in miles (Navy, November, 1901).

2. From two points A and B on a line of earthworks, the bearings of a Boer gun were respectively N. 16° E. (that is 16° east of north) and due north. If B is east-south-east of A, and 2,000 yards from it, find the distance of the gun from A. Scale, 1,000 yards to an inch (Navy, March, 1902).

3. What is meant by the variation or declination of the compass? State the present variation in your neighbourhood.

C. S., 1903.

CHAPTER XIV

SUNDIALS—SIDEREAL AND SOLAR DAYS

SUNDIALS are fairly common both in town and country districts. Some of them are very curious, and you will find it an interesting amusement to photograph or get photographs of all those in your own neighbourhood.

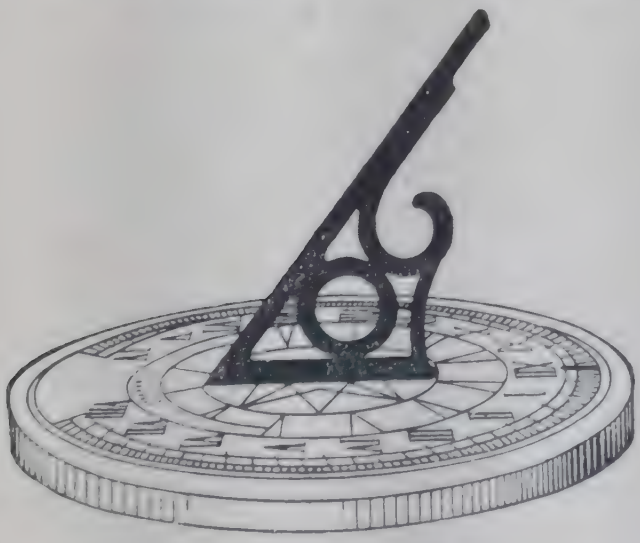


FIG. 40.—HORIZONTAL SUNDIAL.

The sundial is a very ancient instrument. It is said to have been used by the Hebrews over 700 years before the birth of Christ, and the knowledge of its use and construction passed thence to the Greeks and so to the Romans.

Exercise 78.—You can make a very simple sundial in the following way. Take a piece of stiff cardboard and on it

describe a circle of any radius. Divide the circumference into twenty-four equal parts. Number the points i to xii, then i to xii again as shown (Fig. 43). Run a hatpin

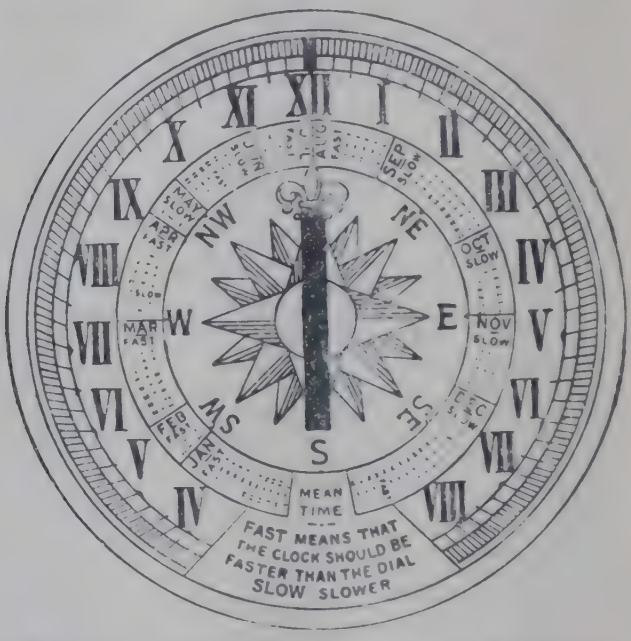


Fig. 41.—Face of Horizontal Sundial.

through the centre of the circle, and by means of sealing wax, fasten it, on both sides, at right angles to the plane of the card. Obtain the true north and south line as in Chapter

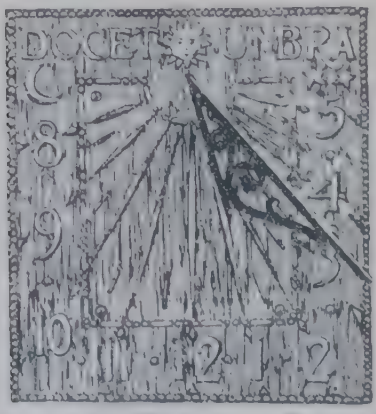


Fig. 42.—Vertical Sundial.

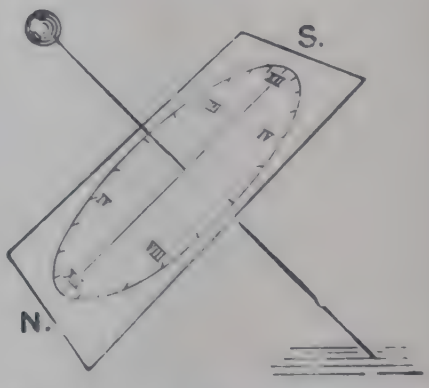


Fig. 43.—A Simple Sundial.

III. Turn the card so that xii noon is exactly over the north and south line. Slope the needle at an angle to the ground equal to the latitude of the place where you are going to put the dial. You can find the latitude of your town your-

self, or from your atlas. The flat circle is the **dial** of the sundial; the hatpin is the **stile** or **gnomon.** It is much more convenient in practice to use a sundial which can be set permanently and securely in either a horizontal or a vertical position. The method of dividing such sundials is much more complicated than that given above.

Unfortunately, sundials are usually rather expensive articles to buy and fix on a building. The horizontal sundial shown in Fig. 41 is made in porcelain and is rather cheaper than one made of other materials.

Exercise 79.—By means of such a sundial, or failing this, by means of your toy one, keep a daily record as follows:—

Date.	Sundial Time.	Watch Time.	Differences.	
			Sun Fast.	Watch Slow.

Get the correct time each day from the post office. The observations are of little value unless your watch is correct. You will find that on certain days in the year the sundial and the watch will practically agree. On every other day the watch will be either faster or slower than the dial. Note carefully the days when the two time-keepers agree and state to what parts of the earth's surface the sun's rays are perpendicular on those dates.

The time as given by the sundial we can call **apparent time**, or sundial time; that given by the watch or clock we can call **clock time.** When the sundial is slower than the clock we have to add a certain amount of time to the apparent time to make it agree with the clock time. On other days, when the sundial is faster than the clock we have to subtract something from the dial time to make it agree with clock time. The time which has to be added

to or subtracted from the sundial time in order to make it equal to clock time is called the **Equation of Time.**

Exercise 80.—Plot a curve day by day from your own observations, giving the clock time when it is noon by the dial. Plot the dates horizontally and arrange the vertical spaces to read minutes from, say, 11.40 a.m. to 12.15 p.m. If on a given day the sundial says it is noon when your watch says it is 12.15, put a dot on the proper vertical line at 12.15 Join the points and notice the shape of the curve. From the chart you can find the amount of time to be added to, or subtracted from the dial time to make it agree with the clock time, that is, you can find the Equation of Time. Compare your results with those given in *Whitaker's Almanack.*

The sundial gives you noon by the sun and so measures solar days. A solar day is the interval between two passages of the sun across the same meridian. If we add together the lengths of all the solar days in a year and divide the total by the number of days in the year we get a **mean solar day**. Clocks and watches are so made that they keep mean solar time. The noon as given by the sun does not agree with the noon as given by the clock, as you will find if you keep a record as explained above. As the clock days are all of the same length, it is evident that the sun days are not all of the same length. One reason for this is, that when the earth is in Perihelion (nearer the sun) it moves more quickly than when it is in Aphelion (further from the sun), so that the intervals between the times when the sun is on the meridian vary.

CHAPTER XV

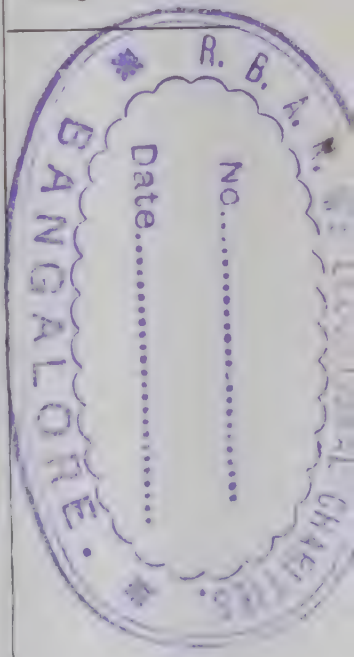
THE ROTATION OF THE EARTH—DAY AND NIGHT

Exercise 81.—Pull down the blinds of the class-room. Put a lighted lamp and a globe on a table, so that the centre of the light is on a line with the centre of the globe. How much of the ball is in shadow ? how much in light ? Turn the

ball round. Does the total amount of light and shadow on the globe change ? Suppose the globe to be the earth and the lamp to be the sun. Those parts of the earth that are in shadow are having their night-time, but wherever there is light it is daytime. What would happen if the sun and the earth were to stand perfectly still ?

The daytime is not always of the same length. In summer you can read without a lamp until late in the evening. In the winter it is dark at quite an early hour. The following figures give the times of the rising and the setting of the sun on certain days of the year in the neighbourhood of London.

Date.	Sunrise.	Sunset.	Length of Day.
	H. M.	H. M.	
Jan. 1	8 8	3 58	
Feb. 1	7 42	4 46	
Mar. 1	6 49	5 36	
Mar. 21	6 5	6 11	
April 1	5 39	6 29	
May 1	4 35	7 19	
June 1	3 50	8 3	
June 21	3 44	8 19	
July 1	3 48	8 18	
Aug. 1	4 23	7 49	
Sept. 1	5 13	6 48	
Sept. 23	5 44	6 2	
Oct. 1	6 0	5 40	
Nov. 1	6 54	4 34	
Dec. 1	7 45	3 53	
Dec. 21	8 5	3 51	



Exercise 82.—Fill in column four, showing the length of the day on the days given.

Exercise 83.—Plot a curve to show the lengths of the days. Plot the dates horizontally and the hours of daylight vertically. Produce your vertical line so that this total length represents 24 hours and completes the rectangle. Turn the figure upside down. What does the curve represent now ? Shade the area enclosed by the curve which represents the variation in the hours of darkness.

We have now to explain why the days vary in length in the way shown above.

In olden days men believed that the earth was a great plane in the middle of the universe. They saw that the sun rose in the east in the morning and set in the west in the evening, and they came to the conclusion that it moved round the earth in a circle.

We now know that the apparent movements of the sun are caused by the real movements of the earth. The earth revolves in space at a distance of 93,000,000 miles from the sun. It also spins round on its own axis, making a complete rotation in *about* 24 hours.

The path of the earth round the sun is called its **orbit**. It is an ellipse in shape, so that the earth is nearer the sun at one time than it is at another. The sun is not in the centre of the ellipse but to one side. When the earth is nearest the sun it is said to be in **Perihelion**. When it is furthest away from the sun it is said to be in **Aphelion.**

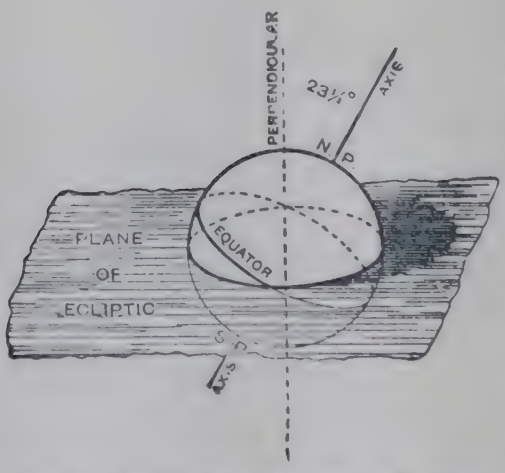


FIG. 44.—INCLINATION OF THE EARTH'S AXIS TO THE PLANE OF THE ECLIPTIC.

Imagine a flat sheet of metal passed through the earth, cutting it in two, along the Equator. This is the plane of the Equator. Imagine another flat sheet to pass through the centre of the sun and the centre of the earth and to cut the earth's orbit at all points. This is the plane of the **ecliptic.** Now as the earth travels in its orbit, its axis is not perpendicular to the plane of the ecliptic. It is tilted as shown in the figure. You will see that the plane of the ecliptic and the plane of the Equator cut one another at an angle of $23\frac{1}{2}°$. The earth's axis makes an angle of $66\frac{1}{2}°$ with the plane of the **ecliptic.** It is at right angles to the Equator, and is always directed to the same point in the heavens.

Consider the position of the earth with regard to the sun

on four different dates as shown in the diagram (Fig. 45) The chief points to bear in mind are that the axis of the earth is not perpendicular to the plane of the ecliptic, that the plane of the Equator cuts the plane of the ecliptic at an angle of $23\frac{1}{2}°$, and that the axis of the earth always points in the same direction. The four dates chosen are June 21, December 21, March 21, September 23. Look in the table given to you and note the lengths of the days on these dates.

Exercise 84.—Put the globe and lamp in the positions

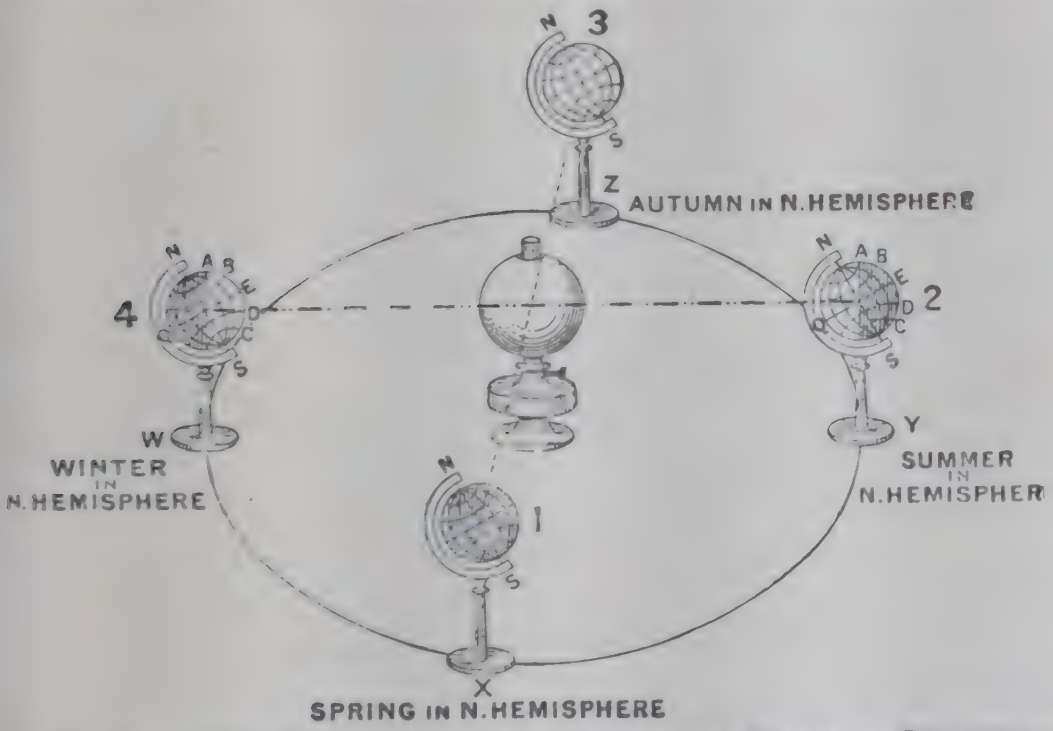


FIG. 45.—EXPERIMENTAL ILLUSTRATION OF THE CONSTANT DIRECTION OF THE EARTH'S AXIS, AND THE CAUSE OF SEASONS.

marked 1 in Fig. 45. This represents the position of the earth with regard to the sun on March 21 (Spring). Find Quito on the globe. An upright stick at Quito on this date would cast no shadow. On what line does Quito lie ? Find a few of the places on the same line. Now if there are no shadows on that line at noon, the sun must be directly over the line at that time.

Do the sun's rays reach the (*a*) North Pole, (*b*) the South Pole ?

Exercise 85.—Turn the globe till London is at the edge

of the shadow. Measure with a piece of string, along a parallel of latitude, the distance London will have to travel before it gets to the other edge of the shadow. That is the length of its path in the light. Measure the length of the path in the dark. What do you notice ? Refer to the table on p. 77. What is the length (*a*) of the day, (*b*) of the night on March 21 ?

Exercise 86.—Put the globe in the position 3, the position on September 23 (*Autumn*). Find Quito again and work through all the questions given in the preceding exercise.

The following diagram (Fig. 46) represents on paper the condition of things you have just been examining on the globe.

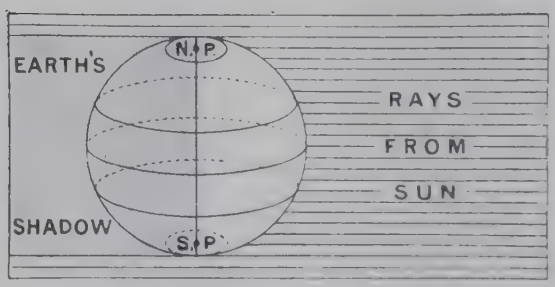


Fig. 46.—Conditions of Equal Day and Night all over the World (March 21 and September 23)

The part of the earth towards the sun is in the light and has day, and the part away from the sun is in the dark and has night. Consider a point on any one of the circles shown and you will see that the arc which it describes in the sunlight (when the earth and sun are in this relative position) is equal to the arc which it describes in the dark. Thus on March 21 and September 23 all places on the earth's surface have their day and night equal. Each place has 12 hours day and 12 hours night. These dates have special names. We speak of March 21 as the **Vernal Equinox,** and of September 23 as the **Autumnal Equinox** (*aequus*, equal ; *nox*, night).

Exercise 87.—Put the globe in the position 2 in Fig. 45. We have the condition of things on June 21 (Summer).

At midday on June 21 there are no shadows of upright objects at the following places :—Cape San Lucas (Lower California), Havana, the first Cataract of the Nile, Mandalay, Formosa. Find these places on the globe. They lie on a line called the **Tropic of Cancer.** What is its latitude ? It is 1,600 miles north of the Equator. As there are no

shadows on this line on June 21, the sun on that day must be perpendicular to the Tropic of Cancer.

Turn the globe round. Is the North Pole ever in darkness? What is the length of the day there? Is the South Pole ever in the light? What is the length of the day there? Measure with string the paths of London and of any place on the Equator in the light and in the darkness. Compare these and say about how long the day and the night will be on that date. Look in the table on p. 83 and note the length of the day and night given there for London.

The following diagram represents the condition of things we have been studying.

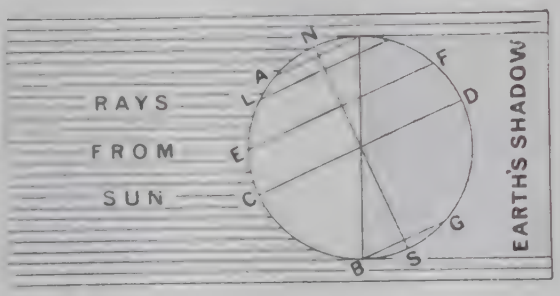


FIG. 47.—CONDITIONS OF LONGEST DAY IN NORTHERN HEMISPHERE (JUNE 21).

In this position the sun's light reaches beyond the North Pole but does not reach the South Pole. C D is the Equator, E F is the Tropic of Cancer, L may stand for London. Two other points A and B are marked. Consider each of these points in turn. In 24 hours the earth rotates once. The point A is never in the dark. At this place the sun does not set and there is no night. The arc described by L in the light is much longer than that which it describes in the dark. The point C is on the Equator. The arc which it describes in the daylight is equal to that which it describes in the darkness, and day and night are of equal length. This is always the case at the Equator. The point B never gets into the light at all. At that place the sun never rises and there is one long night.

How many degrees are there from C to E? from C to N? from E to A? from A to N? from C to B? from B to S? If you cannot reason out the answers, copy the diagram and measure the angles with a protractor. The circle through C and D is the Equator; the circle through E and F (latitude 23½° N. is the Tropic of Cancer, and the circle through B and G (latitude 66½° S) which marks the

southern line of light, which is reached by the sun's rays at this time, is called the **Antarctic Circle.** It is 4,800 miles south of the Equator.

Exercise 88.—Put the globe in the position 4 in Fig. 45. We have the condition of things on December 21.

At midday on December 21 there are no shadows of upright objects at the following places :—Antofagasta (west of S. America), Oran, San Paulo (Brazil), Kalahari desert (South Africa), Southern Madagascar, Rockhampton (Queensland, Australia). All these places lie on a line called the **Tropic of Capricorn,** and as there are no shadows on this line at midday on December 21, the sun must be perpendicular to the Tropic of Capricorn at that time. The Tropic of Capricorn is 1,600 miles south of the Equator. What is its latitude ?

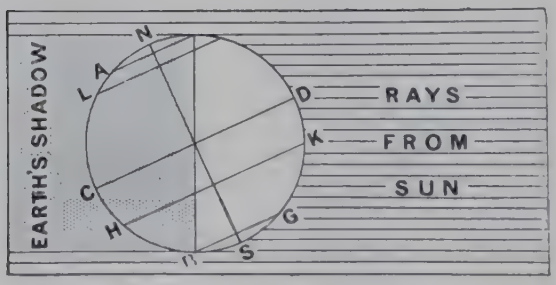


FIG. 48.—CONDITIONS OF SHORTEST DAY IN NORTHERN HEMISPHERE (DECEMBER 21).

Exercise 89.—Turn the globe round and make exactly the same measurements and comparisons as in Exercise 87.

Fig. 48 represents the condition of things.

The letters are the same as in the last figure, but in this one the Tropic of Cancer has been omitted and the Tropic of Capricorn inserted. It passes through H and K. Notice that everything is now changed. A never gets into the light and has one long night, while B is always in the light and has one long day. London is in the light for a short time and in the dark for a long time. What is the length of the day and of the night in London on December 21 ? Points on the Equator still have 12 hours of day and 12 hours of night.

How many degrees are there from N to A ? A to C ? C to H ? H to B ? B to S ? The northern line of light beyond which there is no day is the **Arctic Circle.** What is its latitude ? It is 4,800 miles north of the Equator.

The times of sunrise and sunset at London for several days in June and December are here given.

Date.	Time of Sunrise.	Time of Sunset.
	H. M.	H. M.
June 19	3 44	8 18
„ 20	3 44	8 18
„ 21	3 44	8 19
„ 22	3 45	8 19
„ 23	3 45	8 19
Dec. 19	8 4	3 50
„ 20	8 4	3 50
„ 21	8 5	3 51
„ 22	8 6	3 51
„ 23	8 6	3 52

Observe that for a few days near June 21, the sun rises and sets at about the same time, and that this also happens again for a few days near December 21. The days are of almost equal length and it appears as though the earth were standing still. The ancients thought that it was the sun that was really standing still and so they called June 21 the **Summer Solstice** (*sol*, sun ; and *sto*, stand) and December 21 the **Winter Solstice.**

The word "tropic" means "turning line." When the mid-day sun appears to have reached a point over the Tropic of Cancer it appears to turn south until it reaches the Tropic of Capricorn, when it appears to turn north again. The sun is always perpendicular to some part of the zone between the two tropics.

REVISION EXERCISES

1. Distinguish between the earth's rotation and its revolution. Which of these causes the alternation of day and night and how ? C. J., 1895.

2. Explain why the days are longer in the North of Scotland than in the South of Ireland during summer, and shorter in winter. O. P., 1906.

3. Give a rough comparison of the lengths of the day (i.e., the number of hours the sun is above the horizon) on December 22 and June 21, at the following places : (*a*) Aberdeen (latitude 57° N.) ; (*b*) Dunedin (latitude 46° S.). Account for the differences observed. O. S., 1899.

4. Explain fully the meaning of (i) the plane of the ecliptic ; (ii) the Arctic circle ; (iii) the Equinoxes ; (iv) the Tropic of Capricorn. C.J. 1905.

5. On twelve little sketch maps plot the following times of sunrise at Wick, Yarmouth, Greenwich and Valencia on the first of each month. Then take the month of March. At Wick the sun rises at 7.11. At this hour it has risen at Yarmouth and Greenwich but not at Valencia. Estimate the point between Greenwich and Valencia where it is rising. Draw a line from Wick to this point. The sun will be rising at every point on this line. Shade all the area to the west. Do the same for each month. What do you notice? Can you explain what you notice?

	1st Jan.	1st Feb.	1st Mar.	1st April	1st May	1st June	1st July	1st Aug.	1st Sept.	1st Oct.	1st Nov.	1st Dec.
Wick	9. 5	8.21	7.11	5.42	4.20	3.17	3.11	4. 3	5.13	6.19	7.30	8.38
Yarmouth ..	8. 6	7.38	6.43	5.30	4.24	3.38	3.35	4.13	5. 5	5.56	6.50	7.42
Greenwich..	8. 8	7.41	6.49	5.38	4.34	3.51	3.48	4.24	5.14	6. 2	6.55	7.45
Valencia....	8.51	8.25	7.31	6.19	5.13	4.29	4.26	5. 3	5.54	6.43	7.37	8.28

A very ingenious piece of apparatus called the *Altiscope* can be used for the experimental determination of many of the facts in this chapter. See p. 162.

CHAPTER XVI

THE REVOLUTION OF THE EARTH. THE FOUR SEASONS

THE earth, travelling in its elliptical orbit, makes one revolution round the sun in about 365 days, and this period, which is the time taken to make one complete revolution round the sun, we call a **year.** The distance travelled by the earth in a year is about 600,000,000 miles. About how many miles per hour does it travel?

We have seen how the inclination of the axis of the earth causes the day and night to be of different lengths at different times of the year. This inclination of the earth's axis is also the cause of the four **seasons,** Spring, Summer, Autumn, Winter.

When the sun is perpendicular to the Tropic of Cancer, our days are long and our nights are short. At that time we have sunshine for many hours and darkness for a few. We keep in front of the fire, as it were, for many hours, while we are only shut out in the cold for quite a short time. The weather at this time is warm and we are having **summer.** When the sun is perpendicular to the Tropic of Capricorn, our days are short and our nights are long. At that time the people on the other side of the world, in Australia and New Zealand, get most of the fire and we are shut out for hours in the cold and the dark. We are having **winter.**

When the sun is perpendicular to the Tropic of Cancer, it is high in the sky, and its rays fall upon us at a certain angle. But six months later, when its rays are perpendicular to the Tropic of Capricorn, we see the sun low down in our sky, and its rays fall upon us in a much more slanting direction than they did before.

The difference between the angle at which the sun's rays fall upon us in June and the angle at which they fall upon us in December partly accounts for the fact that we have summer in June and winter in December. Toast two pieces of bread in front of the fire. In the first case, hold the piece of bread parallel to the bars of the grate, so that the

rays of heat fall perpendicularly on the bread. In the second case hold the piece of bread slanting towards the bars so that the rays of heat fall at an angle upon the bread. The first piece will be toasted much sooner than the second. This is merely a simple experimental proof of a well known fact, that more heat is received from a hot body when its rays fall directly upon the object to be warmed than when they fall upon it in a slanting direction. Hence, when the sun is perpendicular to the Tropic of Cancer, not only do we get more sunshine than we do when it is over the Tropic of Capricorn, but we also get the rays more directly in the first case than the second.

Again, when the sun is over the Tropic of Cancer, the rays have to travel through a certain thickness of air before they reach us. When the sun is over the Tropic of Capricorn the rays have to travel through a much greater thickness of air before they reach us. The air, and the moisture in the air, absorb a certain amount of heat. The greater the thickness of air through which the sun's rays have to pass the more are we robbed of the heat contained in those rays.

REVISION EXERCISES

1. What causes determine the succession of the seasons, viz., Winter, Spring, Summer and Autumn, in our latitude? O. J., 1896.
2. Explain why, as a general rule, the temperature decreases as we go from the tropics to the poles. C. J., 1898.

CHAPTER XVII

LATITUDE AND ALTITUDE OF THE SUN AT NOON

In Fig. 49 let B C be a church tower and D the position of the sun. Join D to B by a straight line and produce it to meet the ground line at A. The length A C is the length of the shadow of the church tower at this time. The angle B A C is said to be the angular height of the sun above the horizon or its **altitude.**

Exercise 90.—Take a piece of squared paper. On some

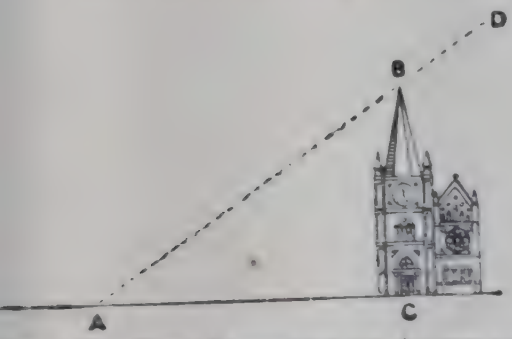


FIG. 49.—THE ALTITUDE OR ANGULAR HEIGHT OF THE SUN ABOVE THE HORIZON.

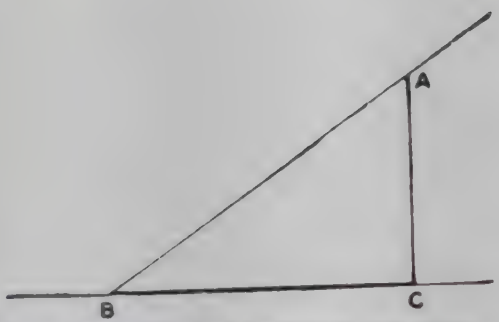


FIG. 50.—THE ALTITUDE OF THE SUN.

convenient scale draw a figure like that shown in Fig. 50. A C represents the stick in the school playground. B C represents the length of the shadow at, say, nine o'clock. Find the angle C B A, that is, find the altitude of the sun. (Use a protractor.) Do this for every one of the measurements you have made throughout the day (see Ex. 70) and enter the results in the third column of your list of shadow lengths. As the shadow shortens does the altitude of the sun increase or decrease ?

Exercise 91.—Sailors require to know each day the altitude of the sun. For this purpose they use an instrument called a **sextant.**[1] A simplified form of this instrument is shown in Fig. 51. It consists of a sector of a circle with a graduated arc of 60°. Attached to the sector is a small plate with a hole in it, E. There is a movable arm D, to one end of which a mirror A is fixed. At B there is another piece of glass. One half is silvered and the other half is plain. Dark glasses are provided to put over the hole at E, *for it is very dangerous to look at the sun with the naked eye.* At C, there is a vernier which assists in reading accurately the angles that have to be observed. Set the movable arm D opposite the zero of the arc F G. Notice that in this position the mirrors at A and B are parallel.

Look through E and B at the horizon. Then suppose you require the angular altitude of a chimney pot or a

[1] The sextant shown in Fig. 51 is a simple form, suitable for school use, and is made by Messrs. P. Harris & Co., Birmingham.

steeple. Move the movable arm until you can see the image of the top of the object on a level with the horizon. Read the angle through which the arm has been moved. This gives the angular altitude of the object.

Find the altitude of the sun in the same way, *but do not forget the dark glasses.* In future, measure the altitude of

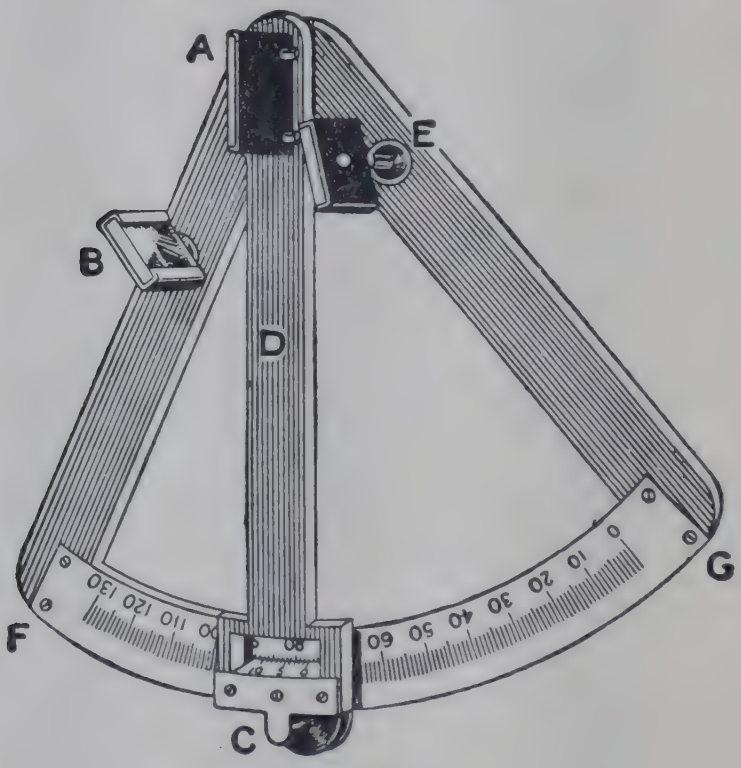


FIG. 51.—SEXTANT.

the sun daily when it is due south, and keep a record of the results.

Why does a sailor require to take the altitude of the sun ?

Consider Fig 52. O is the centre of the earth. E is the position of an observer on the Equator. S is the sun. At noon, the man looks straight up and sees the sun above his head. The point directly above his head is called the **zenith**. (The point directly opposite to this on the other side of the globe is called the **nadir**.) The sun is in the zenith. Imagine a line drawn from the man to the zenith and another one drawn from the man to the centre of the sun.

They will form one straight line. There is no angle between them. The angular distance of the sun from the zenith is 0 degree and the man's latitude is 0 degree.

Imagine an observer at the North Pole. His zenith is at Z. The sun is at S′ and is so far away that its rays may be considered parallel. Now what is the angle between the lines joining the man to the zenith and to the centre of the sun ? It is 90°. What is the latitude of the North Pole ? It is 90° also, and so it can be proved in other positions, that if you draw lines from the observer to the zenith and

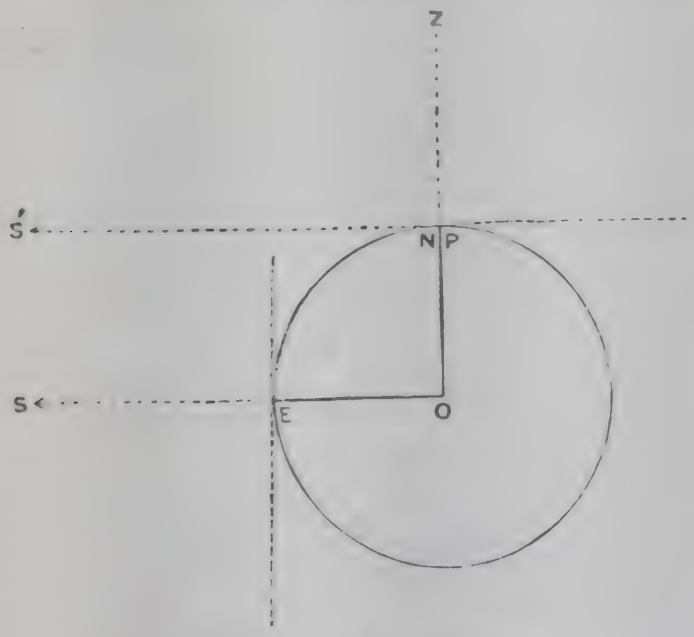


FIG. 52.—THE ZENITH.

from the observer to the sun the angle between these lines gives the latitude of the place. But as it is not easy to tell where the zenith is, we measure the distance of the sun above the horizon and not its distance from the zenith. At the Equator the distance of the sun at noon from the horizon is 90°. Subtract this from 90° and the result is 0°, which is the latitude of the Equator. At the North Pole the distance of the sun from the horizon is 0°. Subtract this from 90° and the result is 90°, which is the latitude of the North Pole. Similarly if the altitude of the sun at noon at your school is 49° then your latitude is $90° - 49° = 41°$. We

have here assumed that the sun is always over the Equator at noon. This however only happens twice in the year at the Equinoxes. But when the sun is north or south of the Equator the difference between the angular altitude and 90° does not give the latitude. When the sun is north of the Equator its noonday altitude is greater to us than when it is over the Equator, and we must subtract a certain number from the observed altitude before we can determine the latitude. When the sun is south of the Equator its noonday altitude is less to us than when it is over the Equator, and we must then add a certain number to the observed altitude before we can determine the latitude. The number to be added or subtracted varies from day to day. The displacement of the sun from the plane of the Equator is called its **Declination.** The Declination is 0° when the sun is over the Equator, and $23\frac{1}{2}$° when it is over one of the Tropics. The declination for each day is given in *Whitaker's Almanack.*

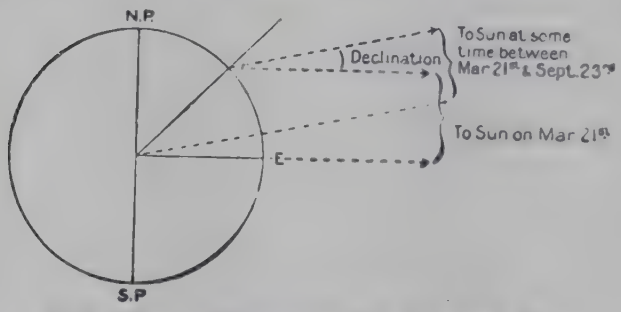


FIG. 53. —DECLINATION OF THE SUN.

Latitude = 90° —Altitude of Sun ± Declination

or

$$L = 90° - A \pm D.$$

Exercise 92.—Find from *Whitaker's Almanack* the Declination of the sun for the days on which you have obtained the midday altitude and calculate the latitude of the school. Take the average of your results: find from a map your correct latitude and note the magnitude of your error.

The latitude of a place north of the Equator can be found at night by observing the altitude of the Pole Star. The Pole Star is almost directly over the North Pole. If you were at the North Pole the distance from the Pole Star to the horizon would be 90°, which is the latitude of the North Pole. At the Equator the Pole Star is seen on the horizon. Its distance from the horizon is 0°, which is the

latitude of the Equator. Similarly if the altitude of the Pole Star at your school is 51° your latitude is 51°.

Exercise 93.—Find the altitude of your school in this way on a bright night.

REVISION EXERCISES

1. How would you determine the correct position of a north and south line by observing the shadows of a stick cast by the sun? C. J., 1901.
2. What is meant by the terms "nadir" and "zenith"? At what part of the earth would an observer see the Pole Star in his zenith? C. J., 1894.
3. Explain how to find the Pole Star, and how, having found it, you could determine your latitude. C. S., 1905.
4. What is meant by the latitude of a place? Why is it stated in degrees? How may it be determined? O. J., 1900.
5. What is meant by the latitude of a place? Give an account of a simple way of finding the latitude of your school (*a*) on March 21 if it is sunny, and (*b*) on any clear night. L. J. S., 1906.
6. Describe any simple method by which you could determine approximately the latitude of the place you live in. What is the highest point above the horizon reached by the sun in latitude 57½° at (*a*) midsummer, (*b*) midwinter? C. S., 1900.

CHAPTER XVIII

LONGITUDE AND TIME

When any meridian is exactly opposite the sun, it is midday or noon at every place on that meridian. It is true noon to a man in London when the meridian passing through London is opposite the sun. It is noon to a man in New York when New York is opposite the sun. But as New York and London can never be opposite the sun at the same time, they can never have noon at the same time. When it is noon at one place it is midnight at a place on the same meridian but on the other side of the globe. The earth rotates from west to east. Hence all places which are west of Greenwich will have noon later than Greenwich, while places east of Greenwich will have noon earlier than Greenwich.

Exercise 94.—Find from your atlas which of the following places have noon before or after Greenwich, and arrange them in two columns :—

Dublin.	Calcutta.	Quito.	Johannesburg.
Edinburgh.	Melbourne.	New York.	Aden.
Paris.	Hong Kong.	Montreal.	Liverpool.
Berlin.	Limerick.	St. Louis.	Portsmouth.
Madrid.	Strasbourg.	Lima.	Nottingham.
Rome.	Archangel.	Capetown.	Bangkok.
Moscow.	Cambridge.	Bombay.	Yokohama.
Vienna.	Buenos Ayres.	Nagasaki.	

Exercise 95.—Find from your map or globe a few places that have noon at the same time as—(*a*) London, (*b*) New York, (*c*) Calcutta, (*d*) Melbourne, (*e*) Cairo.

The world rotates upon its axis once in 24 hours. There are 360° in a circle. Therefore, the earth rotates 15° in one hour. If it takes 60 minutes for a place to travel 15°, then it takes 4 minutes to travel 1°. A place 1° west of Greenwich will have to wait 4 minutes longer than Greenwich before it is noon at that place. Its clocks are 4 minutes slow by Greenwich time. If a place be 1° east of Greenwich it gets its noon 4 minutes before Greenwich, and its clocks will be 4 minutes fast by Greenwich time.

New York is 75° west of Greenwich. To travel 75° takes 5 hours. Therefore, when it is noon at Greenwich it is 7 a.m. in New York. Calcutta is 90° east of Greenwich. To travel 90° has taken 6 hours. Therefore, when it is noon at Greenwich it is 6 p.m. in Calcutta.

By consulting your map find sundial time in Newfoundland, Vancouver, Quito, Tierra del Fuego, North Cape, Ceylon, Brisbane, when it is noon at Greenwich.

Exercise 96.—What time is it in New York when it is 7 a.m. on Thursday in London?

When it is noon in Greenwich what time is it in New Zealand?

When it is noon at Greenwich, what time is it in Calcutta (nearly 90° E.), in New Orleans (90° W.) and in New Caledonia (165° E.)?

C. J., 1894.

Plymouth is 4° west of Greenwich. It therefore has its noon 16 minutes later. Dover is 1° east of Greenwich; therefore it has its noon 4 minutes earlier. But as it would be very awkward if every town in the country kept its own local time, it has been arranged that all towns in

England shall keep Greenwich time. When it is noon at Greenwich, a telegraphic message is at once sent to many post offices and other places, and the clocks at these places are then set to mark 12 o'clock, if they do not already do so. Other countries adopt similar arrangements. Until 1911 the clocks throughout France kept *Paris* time, but the French have now adopted Greenwich time and French and English clocks agree. In North America, the question of clock time is a troublesome one, for there are about 45° difference in the latitudes of New York and San Francisco. It is noon in New York 3 hours earlier than at

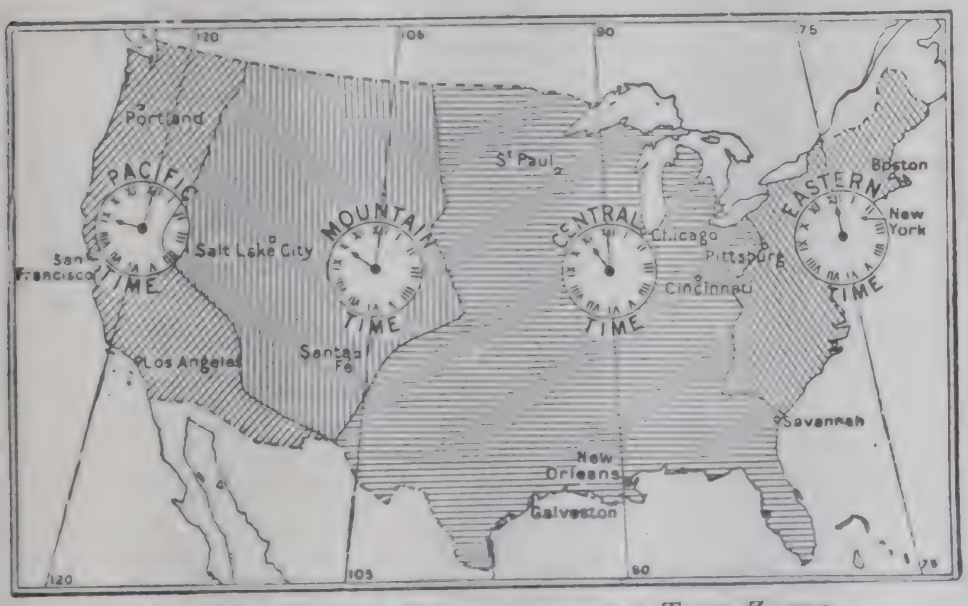


FIG. 54.—UNITED STATES, SHOWING TIME ZONES.

San Francisco. It would be foolish to make the clocks at the two places mark the same noon. The real differences are too great. The United States, for clock times, is divided as shown in Fig. 54, and different standard times are recognized. Each different time is employed over a breadth of 15° of longitude.

When the captain of a vessel goes to sea, he takes with him a very accurate clock called a **chronometer.** This chronometer keeps Greenwich time. Suppose that the vessel is sailing between Liverpool and New York On a given day the captain notices that the sun is at its highest point in the heavens, that is, that it is noon on his meridian. at

a time when the chronometer says that it is 2 p.m. at Greenwich. Comparing the time given by the sun, and that given by the chronometer, he is two hours slow. He knows that in 1 hour the world travels through 15°, and therefore in 2 hours it travels 30°. He must be 30° from Greenwich. As his time is *slower* than that of Greenwich he is to the west. He is in longitude 30° W.

REVISION EXERCISES

1. What is meant by longitude? How is it determined? C. S., 1901.
2. When it is noon in London, what is the time at (*a*) Vancouver, (*b*) Cape Breton?
3. Irish time is about 25 minutes slow by standard time in Great Britain. Explain fully the meaning of this statement. O. J., 1906.
4. The result of a cricket match played by an English team at Melbourne in Australia (longitude about 145° E.) which only finished at 6 p.m. was known here early in the same afternoon. Explain this.
C. J., 1895.
5. At a certain place on December 25 the sun attained its maximum altitude, which was 14°, at 12.5 p.m., Greenwich mean time. The declination of the sun on the day in question was 23½° S. Find the latitute and the longitude of the place where the observations were made.
C. S., 1906.

PART III

MAPS AND MAP-MAKING

CHAPTER XIX

SIMPLE PLANS

Exercise 97.—Take a matchbox. Put the box flat on a piece of paper and run your pencil round the edge. Remove the box. You have here a rough plan of one face of the box. Measure the lengths of the sides with a ruler and write these on the corresponding sides of the drawing. You have made a plan of the matchbox.

Exercise 98.—Measure the length and the breadth of the top of an oblong table : we cannot easily make a tracing showing the shape of the table, but we can draw it "to scale." If the table is 4 feet long and 3 feet wide we can represent it by a rectangle 4 inches long and 3 inches wide : it would then be said to be drawn on the scale of an inch to a foot. Draw the table you have measured on the scale of an inch to a foot.

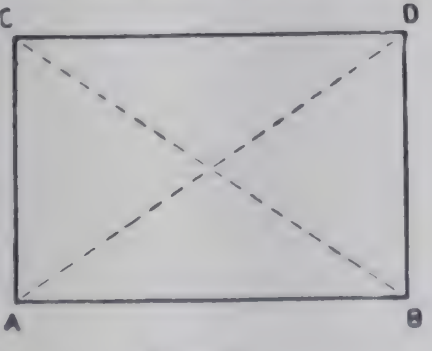


FIG. 55.

Exercise 99.—Draw the same table to the scale of half an inch to a foot.

Exercise 100.—Draw a plan of your desk to a convenient scale : state what scale you have used.

When a foot is represented by an inch any line in the plan is $\frac{1}{12}$ of the length of the original line : the fraction $\frac{1}{12}$ is called the "representative fraction" and is denoted by the letters R.F.

Exercise 101.—What are the representative fractions used in exercises 98 and 99 ?

Such scales as those we have just used would do only for small areas. If we were to draw a map of Rutland, the smallest English county, and if in this case we took half an inch to represent 50 yards, we should require a piece of paper nearly 8 yards square. Many

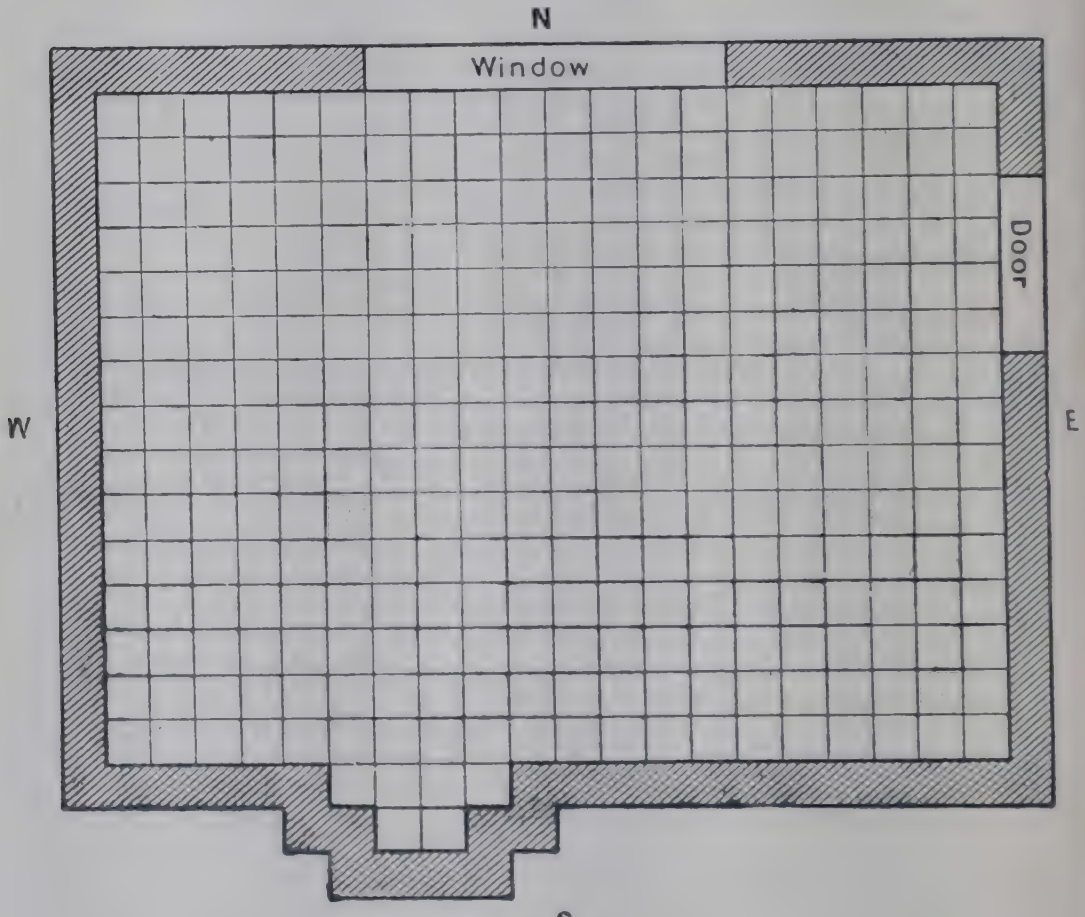


Fig. 56.

Ordnance maps are drawn on a scale of 1 inch to a mile. Now a mile contains 63,360 inches. Therefore the representative fraction (R.F.) is $\frac{1}{63360}$ and the map is said to be drawn at a scale of 1 to 63,360.

Exercise 102.—Examine your atlas and note what are the representative fractions of some of the maps. If the scale is not given you can find it approximately by measur-

ing the distance between two given parallels of latitude A degree of latitude is about 70 miles.

Exercise 103.—Draw a plan of your class-room : state what scale you have used. Are you sure that the angles are right angles ? In order to be sure that the shape is correct measure the diagonals as well as the sides of the class-room, i.e. measure BC and AD. Do not *show* the line BC on your plan, but arrange so that the distance BC is correctly represented : then it does not matter what the angles are. You require to measure only five of the six lines in Fig. 55. Notice that this is so.

REVISION EXERCISE

The fine lines drawn across the plan of a room given in Fig. 56 represent squares of 1 foot each way. You are required to insert on the plan the following pieces of furniture :—

(*a*) A book-case, 2 feet broad and 9 feet long, against the north and west walls respectively.

(*b*) A table 5 feet long, 4 feet broad. One corner of the west end is 3 feet from the window and 7 feet from the west wall ; the longer side is parallel to the north wall.

(*c*) A chair $1\frac{1}{2}$ feet square, $\frac{1}{2}$ foot from the centre of the west end of the table.

(*d*) An easy chair, square in plan, facing the fire-place. One corner is 9 feet from the east wall, and 2 feet from the south wall ; another is 4 feet from the south wall, and 11 feet from the east wall.

C. P., 1908.

CHAPTER XX

SURVEYING WITH THE CHAIN

WHEN one makes a plan of a door or a room it is easy to take the measurements with a foot rule, yard measure, or tape, but when the area to be shown is much larger it is necessary to use a much longer measure ; this measure is the chain. There are three chains in ordinary use, the 50 foot chain, the 66 foot or Gunter's chain, and the 100 foot chain. Chains being of metal can stand the rough usage they receive out of doors. Gunter's chain is seen in Fig. 57 : it is divided into 100 links and at the end of every 10 links a tab is fixed of a particular shape. The 50 foot and 100 foot chains are marked in a similar way, but the units are feet.

When we draw a plan of a table or a plan of a room

we find in most cases that the angles are right angles and the plans are the more easily drawn. Out of doors it is rare to meet with right angles. This, however, presents no

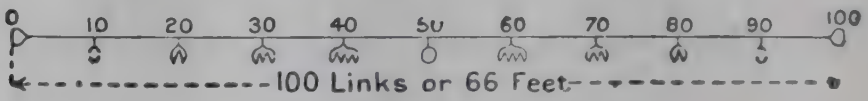


Fig. 57.

real difficulty. Indoors we are never sure that the angles are right angles, and accurate planning must always be based on triangles, as in Exercise 103.

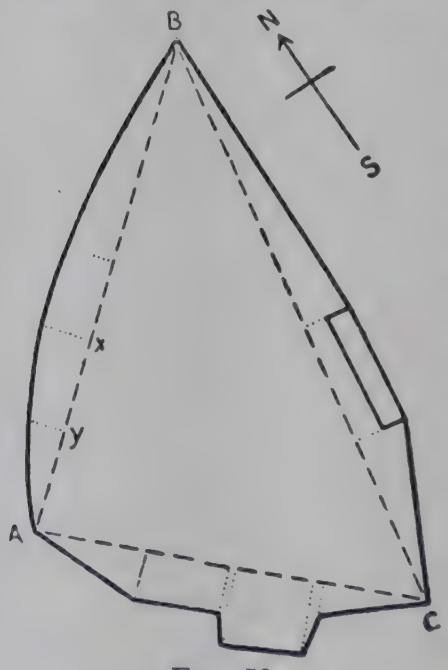


Fig. 58.

There is another and a more serious difficulty. In plans we usually deal with straight lines, but out of doors hedges, walls, streams, and many other things that require to be mapped are not straight but curved and very often change their directions. How the difficulties thus introduced are surmounted is explained by looking at Fig. 58. Here ABC is the playground of a school: the side AB is curved, and buildings make the other sides very irregular. The general shape is found by chaining the lengths AB, BC, CA of the triangle ABC. At known intervals along AB as at x and y, distances, or offsets, are measured to the wall. The field book would show entries thus :—

	B
	375
23	210
27	150
20	80
	0

Line 1 from A north-east to B.

The figures 20 and 27 to the left of the figures 80 and 150 respectively, mean that an offset of length 20 feet has been

drawn to the left at a point 80 feet from A and one of 27 feet at a distance of 150 feet from A.

Exercise 104.—From the data given above for the line AB and from those below for the lines BC and AC, draw the plan on the scale of 1 inch to 50 feet. The figures are given in feet. Draw the construction lines in pencil and rub them out when the work is finished.

		C
		445
35	15	320
35	15	225
		0

Line 2 from B to C.

C	
290	
212	18
205	50
147	55
143	35
80	30
0	

Line 3 from A to C.

It is not usually possible to survey an area by using

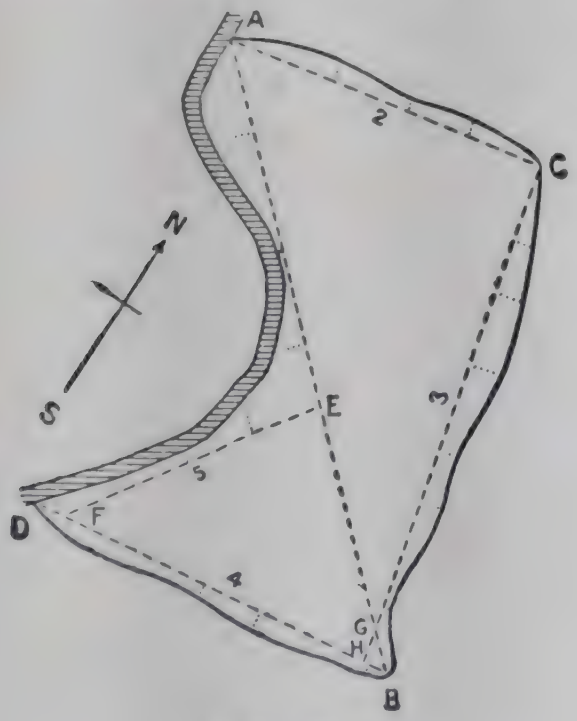


Fig. 59.

only one triangle, as in the example just given, but the work must be based on a framework of triangles.

Exercise 105.— Fasten together at the ends a number of

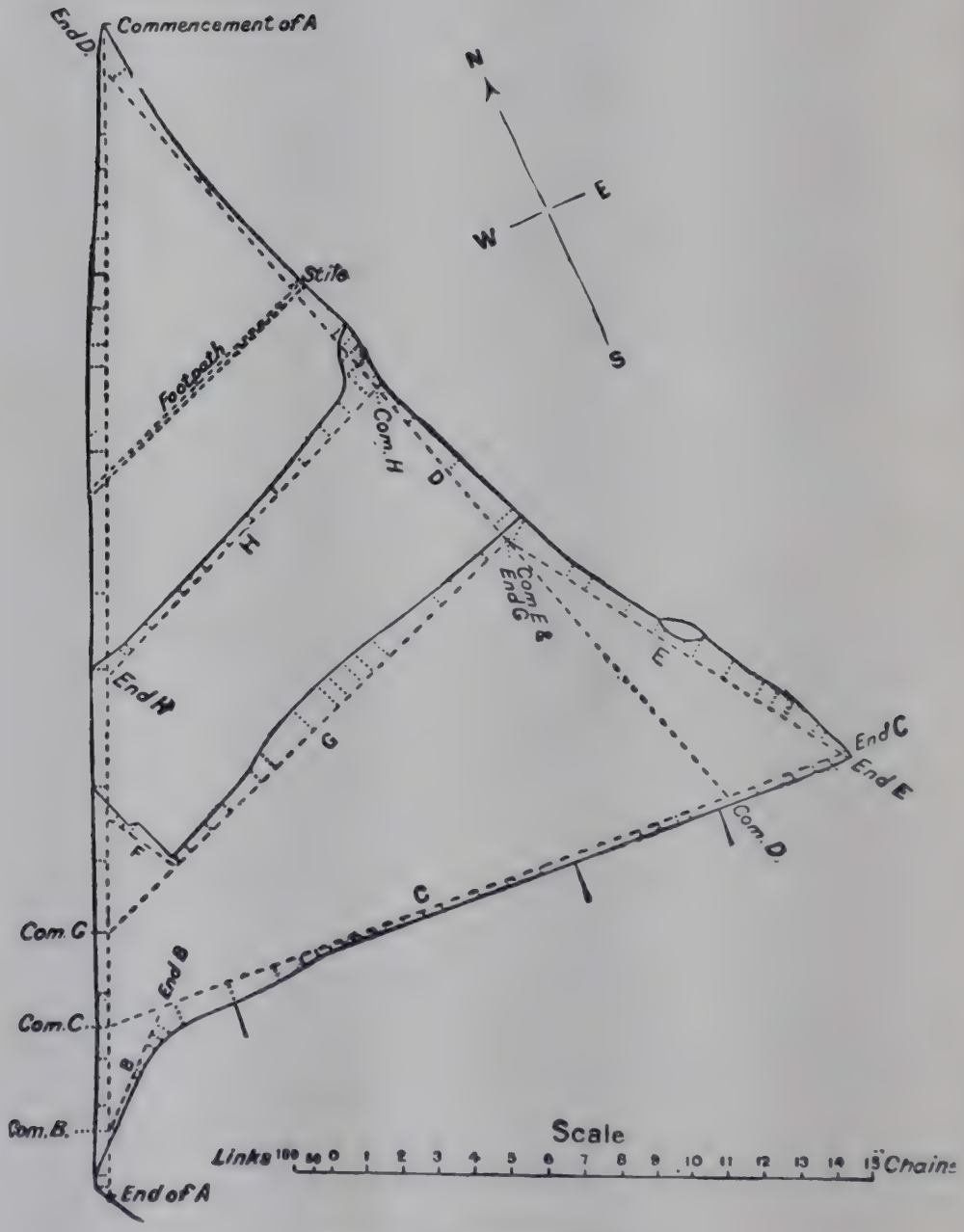


FIG. 60.—CHAIN SURVEY

light laths of different lengths AB, BC, CD, DE, EA : you will find that this framework can take many different shapes. Now fasten another lath across from A to C. The part ABC cannot now move. Fasten another lath so that the framework is rigid. Do the laths require to be fastened at the *ends* to make the framework rigid?

In Fig. 59 the lines AB, AC, CH, BD, EF form such a framework for a field bordered by a river. Notice that the line BD is drawn past the point F where EF meets it, yet D is quite definitely fixed. The corresponding entries in the field book are as under.

to B		to C		to H		to D (hits stream)	
	790		411	⊙	642		490
G ⊙	735	20	317	G ⊙	595	F ⊙	442
E ⊙	460	15	241	9	573	26	410
	380 35	26	142	29	435	24	336
	270 6		0	24	370	17	300
	121 48	Line 2—A to C		45	260	13	242
	55 42			40	170	24	167
	0	to E ⊙ 460 on AB		30	102	18	95
Line 1—A to B			335		0	H⊙	38
		30	267	Line 3—C to H		11	25
		14	172				0
		10	75			Line 4—B to D	
			0				
		Line 5—from F ⊙442 on BD to E.					

Notice that the symbol ⊙ in the field book denotes that another line starts from this point.

Exercise 106.—Draw this area from the entries above on the scale of 1 inch to 100 feet.

Exercise 107.—Survey your own playground or some other suitable area and plot your results : insert the true north and south line.

Surveyors usually employ Gunter's chain. Fig. 60 shows a number of fields surveyed thus from the entries in Figs. 61A and 61B : these entries are given in links or hundredth parts of a chain of 66 feet. The lines by the side of the figures show the way in which the fences, etc., curve.

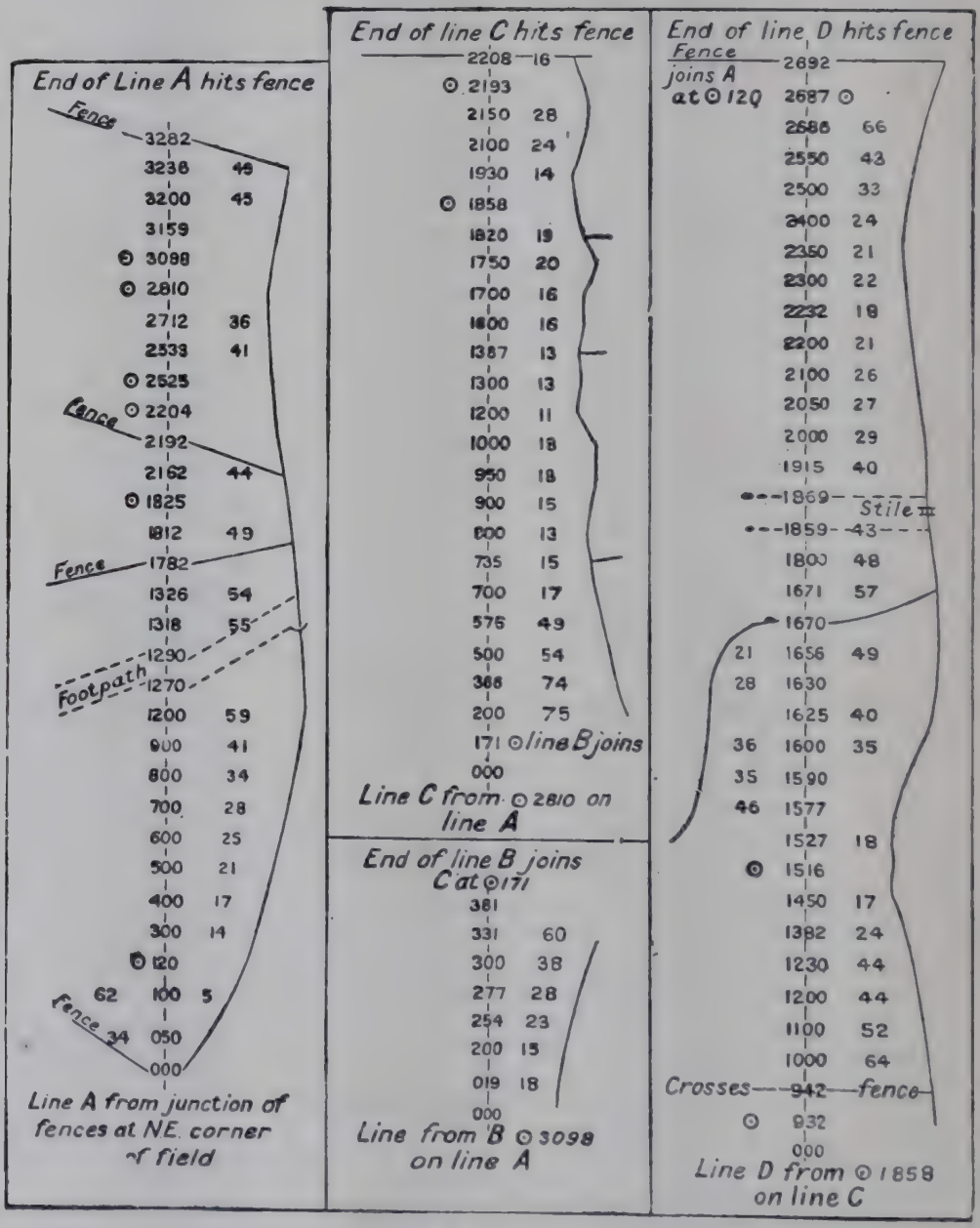

End of Line A hits fence
Fence
3282
3238 44
3200 45
3159
⊙ 3098
⊙ 2810
2712 36
2533 41
⊙ 2525
⊙ 2204
Fence
2192
2162 44
⊙ 1825
1812 49
Fence
1782
1326 54
1318 55
1290
Footpath
1270
1200 59
900 41
800 34
700 28
600 25
500 21
400 17
300 14
⊙ 120
62 100 5
Fence 34 050
000
Line A from junction of fences at NE. corner of field
End of line C hits fence
2208 16
⊙ 2193
2150 28
2100 24
1930 14
⊙ 1858
1820 19
1750 20
1700 16
1600 16
1387 13
1300 13
1200 11
1000 18
950 18
900 15
800 13
735 15
700 17
575 49
500 54
388 74
200 75
171 ⊙ line B joins
000
Line C from ⊙ 2810 on line A
End of line B joins C at ⊙ 171
381
331 60
300 38
277 28
254 23
200 15
019 18
000
Line from B ⊙ 3098 on line A
End of line D hits fence
Fence joins A at ⊙ 120
2892
2687 ⊙
2686 66
2550 43
2500 33
2400 24
2350 21
2300 22
2232 18
2200 21
2100 26
2050 27
2000 29
1915 40
1869
Stile
1859 43
1800 48
1671 57
1670
21 1656 49
28 1630
1625 40
36 1600 35
35 1590
46 1577
1527 18
⊙ 1516
1450 17
1382 24
1230 44
1200 44
1100 52
1000 64
Crosses 942 fence
⊙ 932
000
Line D from ⊙ 1858 on line C

FIG. 61A.

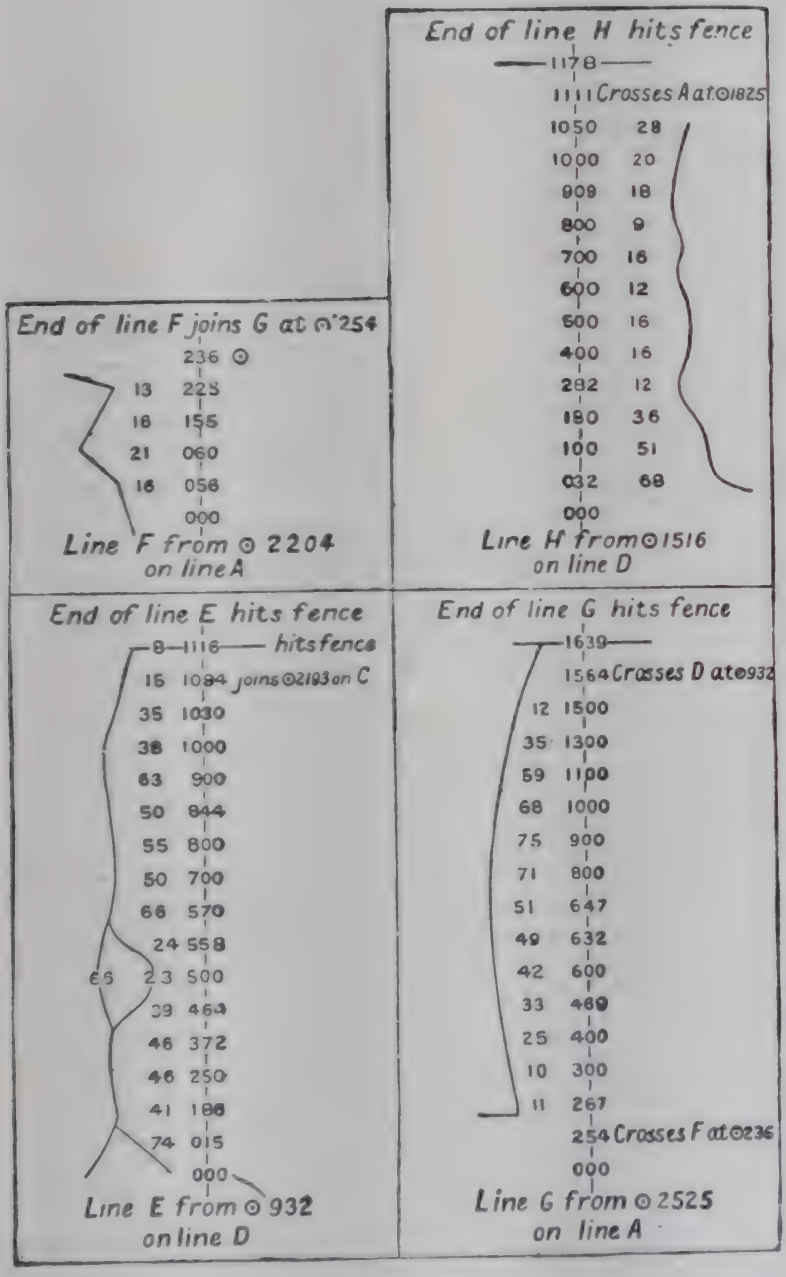

End of line H hits fence
1178
1111 Crosses A at ⊙1825
1050 28
1000 20
909 18
800 9
700 16
600 12
500 16
400 16
282 12
180 36
100 51
032 68
000
Line H from ⊙1516 on line D
End of line F joins G at ⊙254
236 ⊙
13 225
18 155
21 060
16 058
000
Line F from ⊙ 2204 on line A
End of line E hits fence
8 1116 hits fence
15 1084 joins ⊙2193 on C
35 1030
38 1000
63 900
50 844
55 800
50 700
66 570
24 558
65 23 500
39 464
46 372
46 250
41 186
74 015
000
Line E from ⊙ 932 on line D
End of line G hits fence
1639
1564 Crosses D at ⊙932
12 1500
35 1300
59 1100
68 1000
75 900
71 800
51 647
49 632
42 600
33 489
25 400
10 300
11 267
254 Crosses F at ⊙236
000
Line G from ⊙ 2525 on line A

FIG. 61a.

REVISION EXERCISE

Draw a plan of the property surveyed according to the following field book, on the scale of 2 chains to the inch.

⊙ F	485	
⊙ A	0	
Line	4—A	to F

⊙ A	830	
⊙ B	0	
Line	3—B	to A

⊙ B	841	
⊙ p	545	
⊙ D	0	
Line	2—D	to B

⊙ D	1,190	
⊙ n	815	
⊙ m	559	
⊙ A	0	
Line 1	—A south-east to D.	

⊙ p	452	
⊙ m	0	
Tie line	e—m	to p

⊙ m	153	
⊙ E	0	
Tie	line—	E to n

⊙ n	672	
⊙ E	445	
⊙ F	0	
Line	5—F	to n

C. 1907.

CHAPTER XXI

THE PRISMATIC COMPASS—THE PLANE-TABLE—THE THEODOLITE

In Chapters XIX and XX we have dealt with plans and surveys in which we can measure the sides of triangular frameworks by means of foot rules and chains. In the case of larger areas and in the case of some small areas it is impossible to measure all the distances necessary because of intervening obstacles. There must always, however, be a triangular framework. This framework is obtained by measuring only a few distances with the chain and by finding the shapes of the triangles by the measurement of angles. A number of methods are employed: which method is employed in a particular case depends on the degree of accuracy necessary, the scale on which the area is to be surveyed, and on the time which may be given to the work.

The Prismatic Compass.—By means of the prismatic compass angles are found between the direction of

the north point and the directions of certain fixed objects. A compass card divided to every 20′ or third part of a degree is attached to the upper surface of the magnetic needle so as to swing with it. On pressing the spring Z quickly the card is brought to rest. A mirror M is provided for the purpose of taking angles to points on much higher or lower

FIG. 62.

FIG. 63.

PRISMATIC COMPASSES.

elevations than that on which the observer is standing.

There is a sight at S with a vertical line I down the centre. There is a prism at P. Look through the little hole on the left, and turn the instrument till the line I coincides with the object the position of which it is desired to fix. You can see the object and the number of degrees by which that direction diverges from north both at the same time. The method of surveying will be understood from the following figures and diagram.[1] We have here the page from the surveyor's notebook as he wrote it in the field, and the plan which he afterwards made at home.

Start at station I, and look to station II. The divergence of this line is 77° from the north. Measure the line. It is 177 yards long. Write 77° just above I in the notebook, and 177 just under ○ II in the notebook. The curves on the sides of the central column indicate the way in which

[1] These are taken from Edgerton's *Maps and Map Drawing*, by the kind permission of the publishers, Messrs. Macmillan & Co.

the road bends. At 30 yards from I, you are 8 yards from the right hand side of the road, and 7 yards from the left hand side of the road. Sight the church. The line of sight diverges 5° from the north. At 130 yards from I you touch the left hand side of the road. The right hand side is 15 yards away. At this point there is a cottage which is 18 yards long.

Go to station II and sight station III. This line of sight

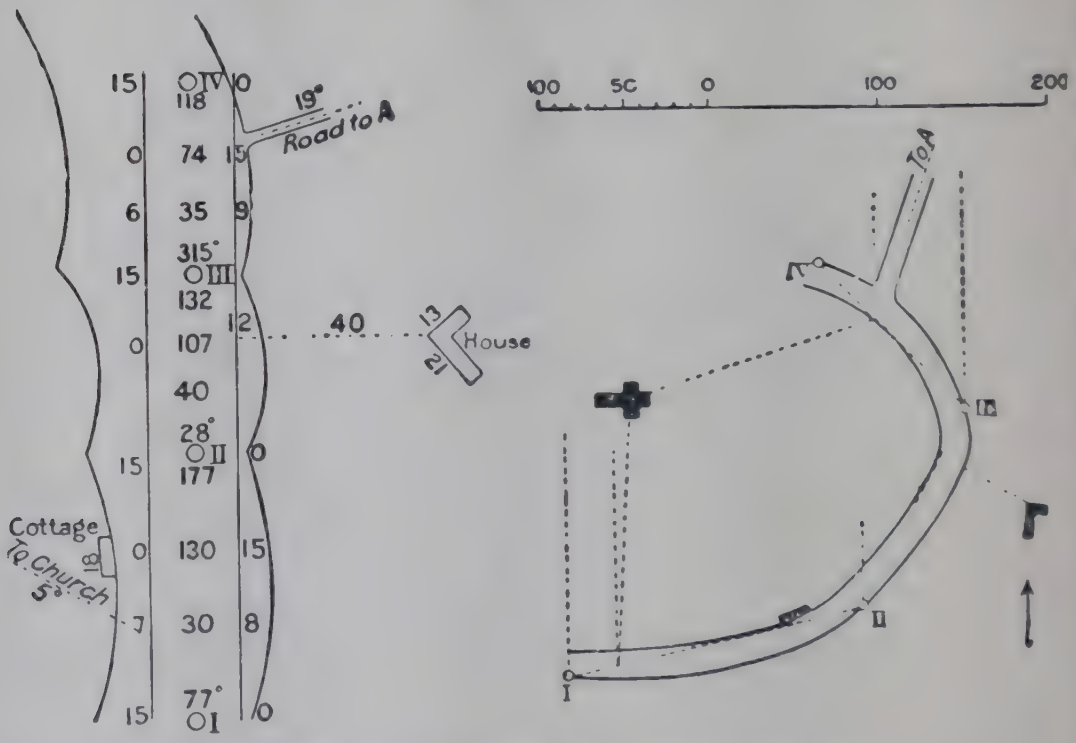


Fig. 64.—A Prismatic Compass Survey.

diverges 28° from the north. Write 28° above II. Measure the line. It is 132 yards long. Write 132 under III. At a point 74 yards from III, the church is observed again. The angle measured this time is 251°.

In actuai practice the surveyor observes and registers the directions of objects, etc., as he goes along. You will find it more convenient in the one or two simple compass surveys that you may make to measure the whole distance from one station to the other first, and then go back to the first station and insert the various details required.

To plot the survey, proceed as follows. Choose a con-

venient scale. Draw on your paper a line to represent north and south. Fix the point I. With a parallel ruler draw a line parallel to the north and south line. Make an angle at I equal to 77° with a protractor. Draw a line. Cut off a length 177 yards. This gives you point II. At the point II draw a line parallel to the north and south line, make the angle of 28° with it and proceed as before. It will be noticed that a triangle I, II, III, has been constructed, with its points definitely fixed since the lengths of two sides and the angle between are known.

Exercise 108.—Make a survey of a piece of road near the school by means of the prismatic compass.

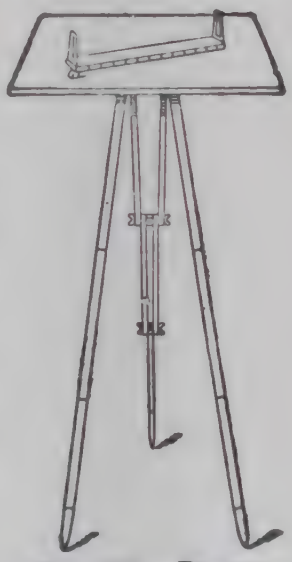


Fig. 65.—Plane-Table.

A Plane-Table (Fig. 65) consists of a drawing-board and a stand on which to place it. The board can be carried separately from the stand, and can be turned about without moving the legs of the tripod which supports it. The accessories comprise a sight rule, a spirit level, a compass, and a chain or tape. The sight rule (Fig. 66) is a ruler with "sights" at each end. The back-sight has a narrow slit in it, and the fore-sight has also a slit, but in this case it has a vertical wire fitted into it.[1]

Fasten a sheet of paper on the table; set up the plane-table as level as possible with the aid of the spirit level, and with the centre of the tripod over station A (Fig. 67). Draw a line in a convenient position on the paper showing the north and south line as determined by the compass, in order to show the geographical position of the plan when plotted and to check the accuracy of the work by placing the compass occasionally on the line representing north and south. If the work is correct the needle will coincide with the pencil line on the paper.

Make a mark on the paper to represent the point A. This should be over the station A. Sight the point B

[1] Messrs. G. Philip & Son supply a cheap Plane-Table. See p. 162.

(Fig. 67) and draw a line in the direction AB. Measure the distance AB on the ground. This is called the base line.

Fig. 66.—Sight Rule.

Mark off AB on the paper to the scale you have decided upon. This fixes the position of B Next sight the points X and Y, drawing lines in their directions from A and marking the lines "to X," "to Y." Take the table to B and set it up with the point representing B on the paper over the station B. Sight A and turn the table till the line BA points to A. Sight X and Y and draw lines from B until they intersect at x and y those drawn to the same points from A : then "x" and "y," on the paper represent X and Y on the ground. In practice you do not require to draw the lines Bx, By : just mark off on Ax, Ay the points of intersection.

The operation can be repeated to any extent, and any other points seen on the ground can be fixed in the same way, or the table may be moved to X and Y and these used as observation stations without any farther measurement of distance.

The great advantage of the plane-table is that by its means angles are at once laid down, and points fixed in the field : there is less liability to make numerical slips. The plane-table is most suited for surveys on the scale of $\frac{1}{2}$ inch or an inch to a mile up to 6 inches to a mile, in which main features such as tops of hills, church towers, outstanding

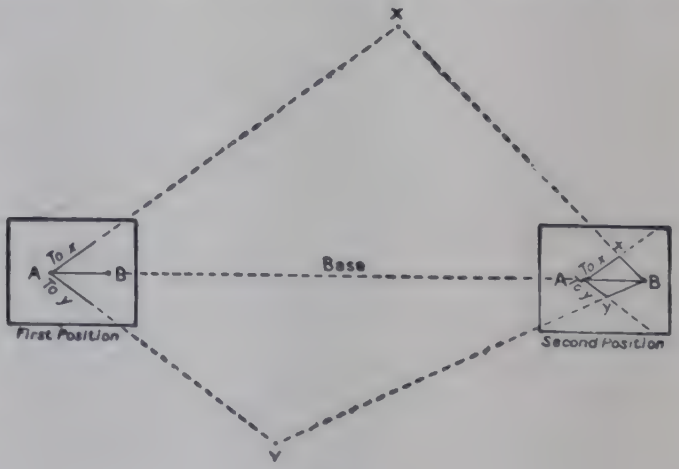


Fig. 67.

trees and other prominent objects are fixed in the triangular framework and the other features sketched in by eye. The plane-table may be used for surveying quite small areas, but chain surveys of these are usually much more accurate than plane-table surveys.

Exercise 109.—Measure a base line and execute a survey of your playground. Note how long it takes and compare the result in time and accuracy with your chain survey.

The Theodolite.[1]—The theodolite is used to construct triangular networks with very large sides. In principle it is very simple, but theodolites which are in use are rather complicated by adjustments to ensure accuracy.

A very simple form of theodolite is shown in Fig. 68. Here a sight rule A is attached to a pillar B which is free to turn about a vertical axis. The pillar is set in a cylindrical block of wood E, and pointer C shows on the scale D through how many degrees the pillar and the sight rule have been turned horizontally. Thus in the area surveyed in Fig. 64 to find the angle between the lines I, II and II, III place the instrument at II, sight the station I, and note the reading indicated by the pointer C, then turn the sight rule round till the station III is sighted and note the new reading of the pointer. The difference between the two readings gives the angle I, II, III.

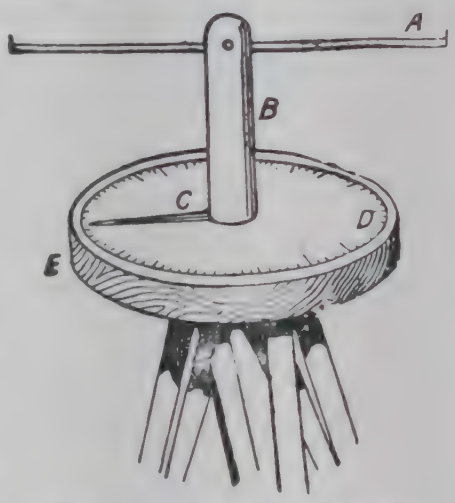


FIG. 68.—A SIMPLE THEODOLITE.

Exercise 110.—Survey a block of buildings bounded by four streets, using the chain to measure the distances and a simple theodolite to measure the angles.

The theodolite can also be used to construct triangular frameworks after a base line has been measured. It is for this purpose that in practice a theodolite is commonly used. The method is much the same as that adopted in

[1] For a simple and cheap form of Theodolite see p. 162.

plane tabling, except that the length of the base line and the values of the angles are noted in the field and the points plotted later. The complete theodolite is shown in Fig.

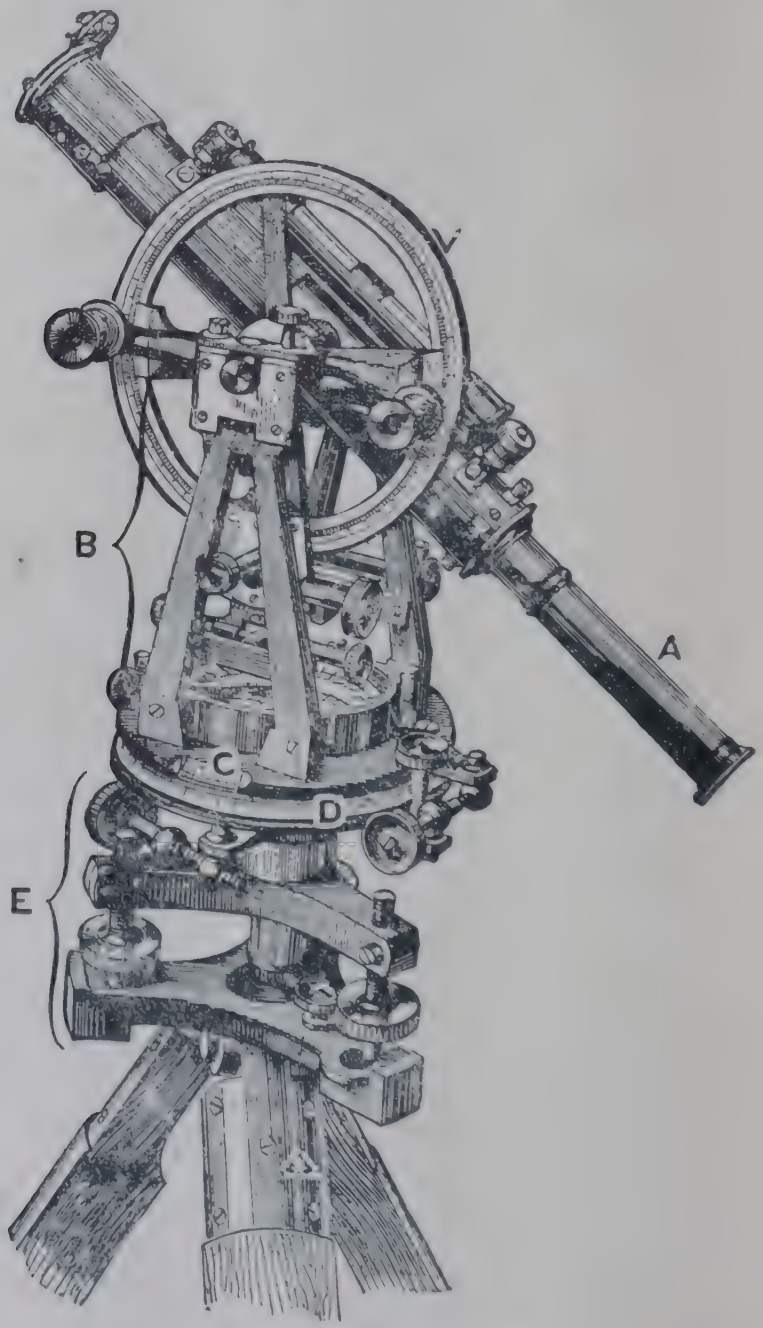


FIG. 69.—THEODOLITE.

69. The parts are lettered to correspond to those of the simple instrument. A telescope takes the place of the

sight rule, and in addition there is a vertical scale of degrees, to show how the telescope has been rotated about a horizontal axis. With such an instrument as this the sides of the triangles that are measured may be 100 miles long.

In mapping a country then, the area is covered by a few large triangles with sides of 10 to 50 miles and averaging over 30 miles. Within these triangles others are made with sides averaging about 5 miles; within these again others with sides of about a mile are surveyed. The length

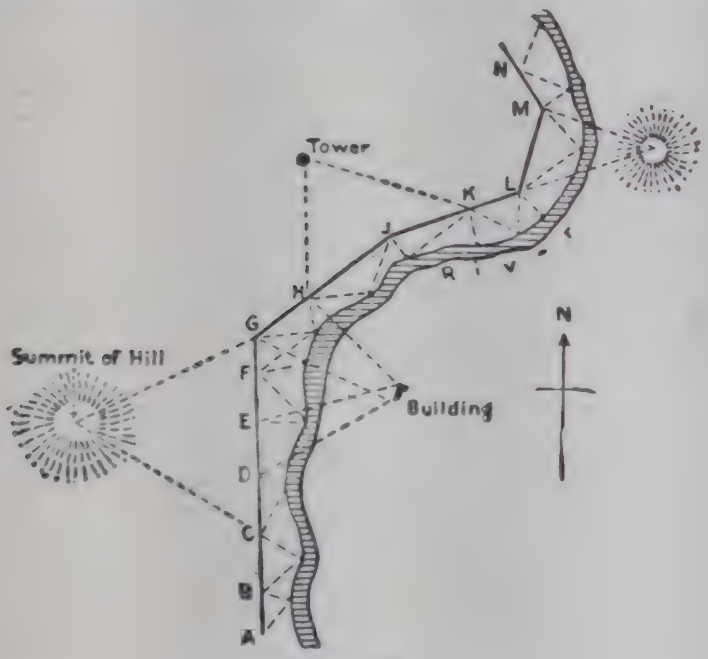


FIG. 70.

of the base line from which the first series is measured must be found very accurately. The smaller details are then filled up by means of plane-table, prismatic compass, and chain.

The whole of the survey depends on the principle of (1) triangulation, (2) proceeding from the whole to the part.

REVISION EXERCISES

1. If you had to survey the area shown in Fig. 70, what instruments and methods would you use if the map is drawn on a scale of (*a*) 1 inch to 200 feet, (*b*) 3 inches to a mile, (*c*) $\frac{1}{4}$ inch to a mile. For which of the methods is the network indicated suitable?

2. The surveys from which maps are drawn usually depend chiefly on *triangulation from a base line*. Explain shortly what is meant by this.
O. S., 1907.

3. How would you set about making a map of a zigzag road, given an ordinary or prismatic compass?

4. A village A is 5 miles from another village B, and 4 miles from a third C, while B is 6 miles from C. Draw a map, stating what scale you choose, and determine the position and distance from A of a church which is 2 miles from C and 4 miles from B.

5. A man walks 7 miles north-east, then 5 miles north, then 6 miles north-west. How far is he in a direct line from his starting point?

6. A and B are two church spires 5,000 feet apart, B lying due east of A. From a third point C it is observed that A lies exactly north-west, and B north-north-east. Draw a rough plan showing approximately the relative positions of A, B, and C; and explain how, with the aid of a graduated rule and of a protractor for measuring angles, you would proceed to draw a plan accurately to scale.

C. S. 1906.

CHAPTER XXII

LATITUDE AND LONGITUDE NETWORKS [1]

We have now seen how a country is mapped; in carrying out this work the mapmaker is met by a difficulty which is of even greater importance when larger areas still have to be mapped; the surface of the world is curved while the map is flat. Further, the method of triangulation fails to determine the relative position of two areas which are separated by a large expanse of water; we must discover some other method by which we may map such areas.

Choose some small portion of the surface of a globe. Imagine that you could cut this little piece out and press it flat upon a piece of paper. The flattened piece would be so much like the curved piece that very little distortion of shape would be produced. But consider a large area, such as the continent of Asia. If you attempt to flatten that out in the way suggested above, you will see at once that the flat map will not represent the curved one. The shape of the continent will be distorted. Again, suppose that you could stand outside the earth and produce a flat map by photography. You would get, in one given position,

[1] The greater part of this chapter should be omitted except by advanced pupils. For graphic illustration Dr. Herbertson's Map Projection Apparatus should be used. See p. 162.

a view like that shown in Fig. 71. Now ABC represents approximately half the circumference of the earth, measured along the equator, and ADC represents approximately half the circumference of the earth as measured along a great circle through the poles. These two lines, on the earth's surface, are very nearly equal. But in the photograph, one is much longer than the other. Therefore, in a flat map, not only is the shape of a large area somewhat incorrect, but the distances also are not correct.

A number of methods have been adopted for drawing flat maps. They are all incorrect in some point, as only a curved map can properly represent a curved surface.

FIG. 71.—THE WORLD IN SPACE.

All the methods depend on drawing networks of latitude and longitude lines and on finding extremely accurately the latitude and longitude of a few points in each country so that the triangulation networks may be fitted into their proper places. In some of these networks areas are correctly represented, in others the shapes of small areas are correct, in others the directions of points from some point or point are correct, in others lines of latitude are parallel lines. The method adopted in making the network depends on the purpose for which the map is required.

In this chapter various ways are described in which networks are constructed to suit the various purposes for which maps are made. Unfortunately the map nets that are really useful are not those which can be obtained directly from a globe by geometrical projection, but are those which are constructed according to some fixed law so that they have some particular property or properties. These networks are not usually simple, so that the first networks that we shall notice are those which are more easily understood though they are not used.

Polar Orthographic Projection.—Suppose that

ACB (Fig. 72) represents a portion of the earth's surface and that points 1, 2, 3, etc., are equally distant from each other. Imagine that DE represents a flat surface on which the map is to be drawn. Drop perpendiculars from 1, 2, 3, etc., to the line DE. Notice that in the centre the distances of the points from one another are fairly uniform, but that as you get towards the ends of the line they become too near together. This projection is called the **orthographic projection.** It is not much used. From a point above the poles, the meridians appear as straight lines, and the parallels of latitude as a series of concentric circles. Here the lines are drawn for every 15 degrees.

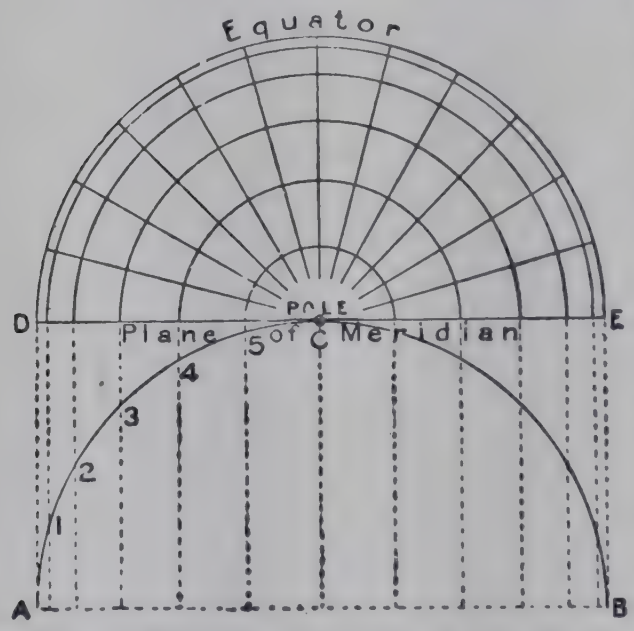


FIG. 72.—POLAR ORTHOGRAPHIC PROJECTION.

Exercise 111.—Draw a polar orthographic map net of a hemisphere showing lines of latitude and longitude for every 10 degrees ; insert the outlines of the Arctic Ocean and North America.

Meridian Orthographic Projection.—In this network the plane of projection is supposed to touch the Globe at a point on the Equator. The lower part of Fig. 73 is the projection we have just constructed—the polar orthographic. DE represents a flat surface touching the globe at the intersection of meridian and the Equator. A is a point on the Equator in longitude 45° : A^1 is the corresponding point on the Equator represented by DE. A^2 is a point in latitude 45 : A^3 is the corresponding point on the meridian network. In the same way B^3 corresponds to B^2 so that A^3B^3 is the projection of the line of latitude 45°. The other lines of latitude are found in the same way.

The line of longitude of 30° is found by noticing that to P, the pole, corresponds P^1; to Q the intersection of latitude 75° and longitude 30° there corresponds Q^1 found by drawing through Q a line QQ^1 parallel to PP^1; to R the intersection of latitude 60° and longitude 30° there corresponds R^1 found by drawing RR^1 parallel to PP^1, and similarly for S^1, T^1, U^1 and V^1. The line of longitude 30° on the meridian orthographic projection may then be obtained by joining P^1 Q^1 R^1 S^1 T^1 U^1 V^1 by a smooth curve. In the same way the other meridians may be constructed. You should notice that the curved lines on the polar projection are the straight lines in the meridian projection and vice versa.

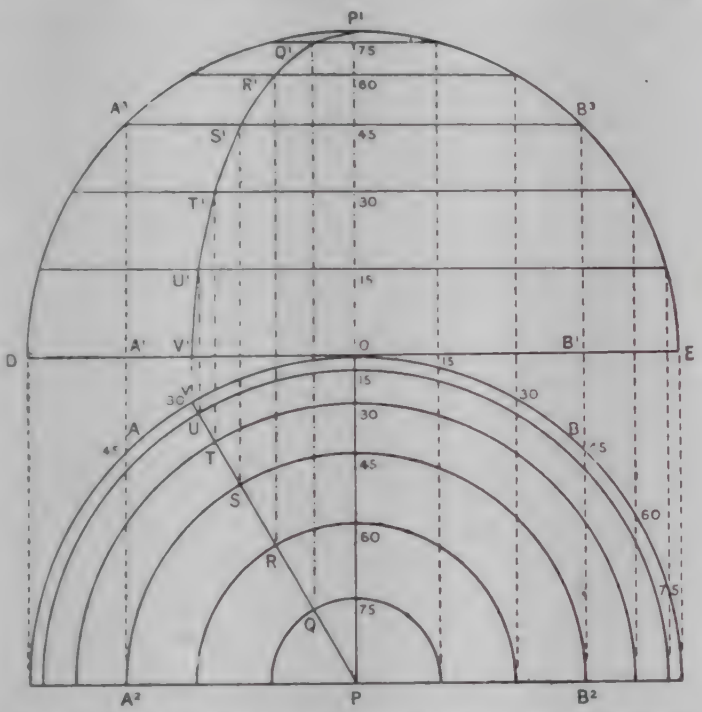


FIG. 73.—MERIDIAN ORTHOGRAPHIC PROJECTION

Exercise 112.—Draw a circle $4\frac{1}{2}$ inches radius: let this represent the outline of a hemisphere. Draw lines of latitude and longitude for every 10 degrees on the Meridian Orthographic Projection: insert the outline of North America.

Stereographic Projection.—Suppose that ABH represents the globe, that your eye is at A, and that you can see right through the sphere. Let NP be the flat surface on which the map is to be drawn. Choose a number of points equally distant from each other, e.g. E, F, G, etc., and from A draw a series of lines through each of these points to the line NP. You will see that the points near the middle are rather too close together, while the points

near the ends are separated too widely. All circles on the globe are represented by arcs of circles on the map, and lines cutting one another on the globe cut one another at the same angles on the map. The distortion of parts of the map near the edges is not so great as in the Orthographic Projection. The **Stereographic Projection** is used only for making maps of the hemispheres.

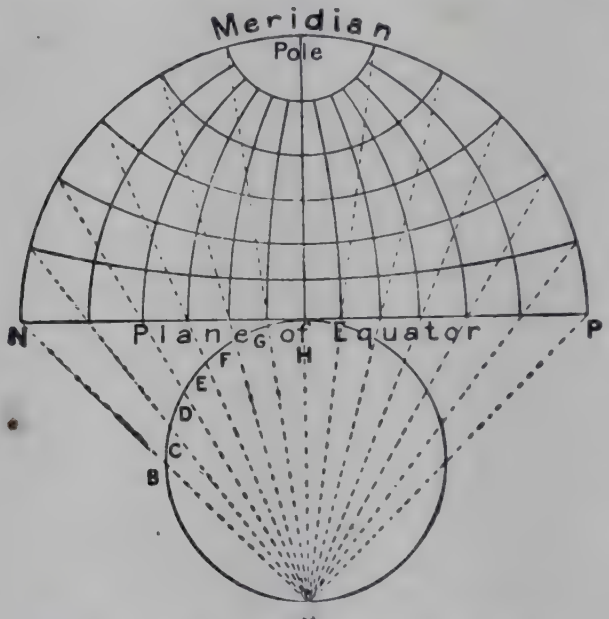


FIG. 74.—STEREOGRAPHIC PROJECTION.

Central Cylindrical Projection.—In the above networks we have described how parallels and meridians are projected directly on to a plane. We may, however, imagine that the globe is in a cylinder, and that lines are drawn from the centre of the

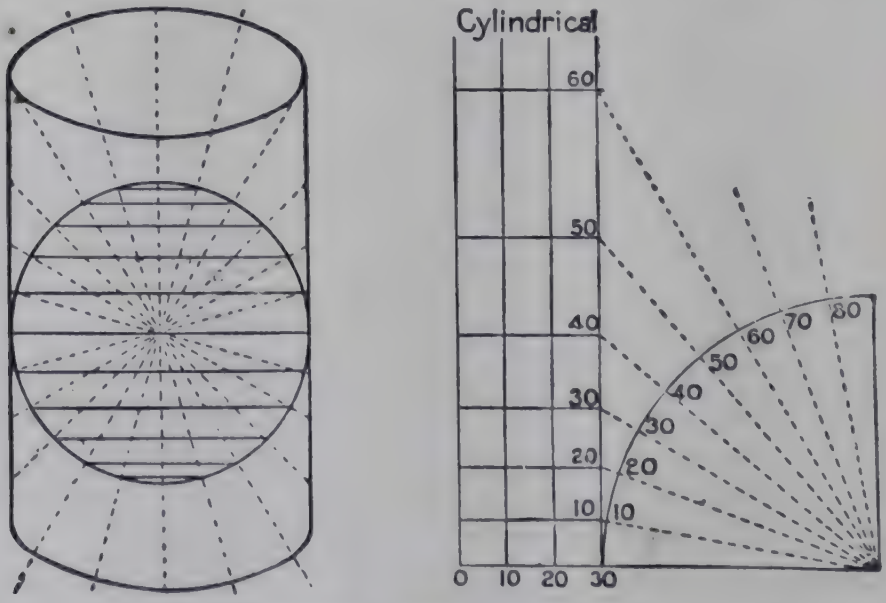


FIG. 75.—CENTRAL CYLINDRICAL PROJECTION.

globe so as to project the points on the surface of the globe upon the internal surface of the cylinder. Cut the cylinder open and roll it out flat. There is no pole on such a map, for its projection does not fall on the surface of the cylinder. The distance between the parallels is exaggerated, and the meridians, instead of meeting at a point, are parallel lines at equal distances from each other.

Cylindrical Equal Area Projection.—If instead of projection from the centre on to a plane we project from the axis of rotation orthographically on to a cylinder wrapped round the globe and touching it at the Equator we obtain a network which has the property that equal areas on the globe are represented by equal areas on the map. From this property it obtains its name. To

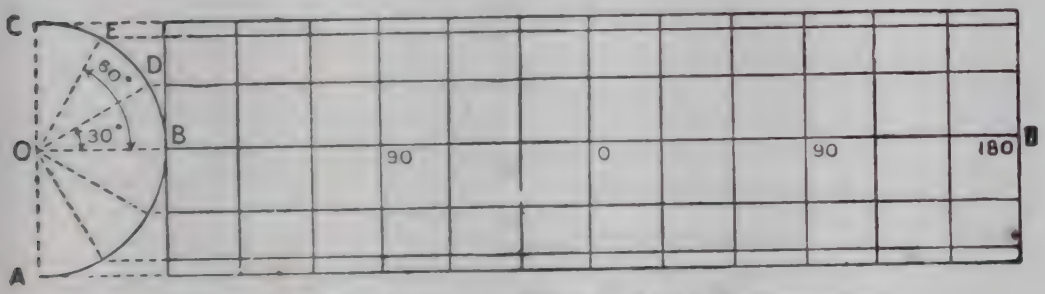


Fig. 76.—Cylindrical Equal Area Projection.

construct a network on this projection to show the whole world with latitude and longitude lines for every 30°, proceed as follows: draw a semicircle ABC (Fig. 76) with centre O. This represents a section of the globe along a meridian. Mark off angles BOD, BOE of 30° and 60°. At B draw a line parallel and equal to AC so that B is the mid point. Produce OB to B^1 so that BB^1 is equal to the circumference of the circle ABC. The circumference may be found by measuring OB and multiplying this length by 3·14. Divide BB^1 into twelve equal parts and through each point of division draw a line parallel to AC. Through DE and C draw lines parallel to BB^1 proceed similarly for the southern hemisphere. This projection is not suited for maps far removed from the Equator.

Exercise 113.—Draw a network on the cylindrical equal area projection; show parallels and meridians for every

15 degrees ; number these and draw maps of Africa and North America in their correct positions. Which area is most correctly represented ?

Central Conical Projection.—This projection is used for making a map of a small part of the earth's surface, say a map of Europe. A hollow cone is placed over a globe, so that it just touches the central parallel of the country of which the map is required. Imagine that lines are drawn from the centre of the sphere through various points on the globe to meet the internal surface of the cone. The projection of the pole falls at the apex of the cone. The parallels of latitude are projected as circles, and all the meridians are projected as straight lines running to the

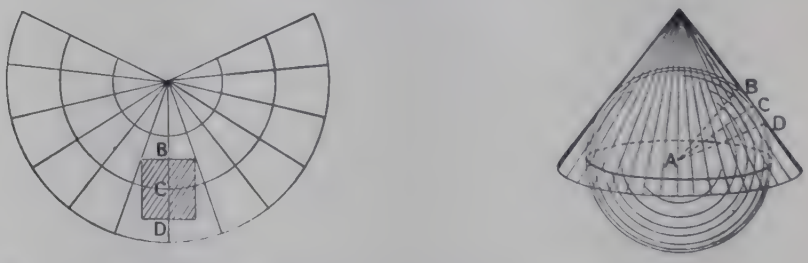


FIG. 77.—CENTRAL CONICAL PROJECTION.

pole. Unfold the cone and spread it out on a flat surface. Except near the apex of the cone, the map is only very slightly distorted.

To construct this projection with 30° N. as central parallel and 0° as central meridian proceed as follows. Draw a circle EPE^{1}S with centre C ; P is the North Pole, E is a point on the Equator. Draw the angle ECA equal to 30°. Draw the tangent AO to the circle, meeting CP produced in O. Make the angles DCF, DCG, DCA equal respectively to 15° 45° and 60° and produce the arms of those angles to meet OA as in Fig. 78A.

Take another point O^1 and with centre O^1 and radii OD, OF, OA, OG, OH draw parts of circles as in Fig 78B.

The length of the line of latitude 30° on the globe is the circumference of the circle whose radius is BA. When the cone is cut open and spread out it has become part of the circumference of a circle whose radius is OA. Since

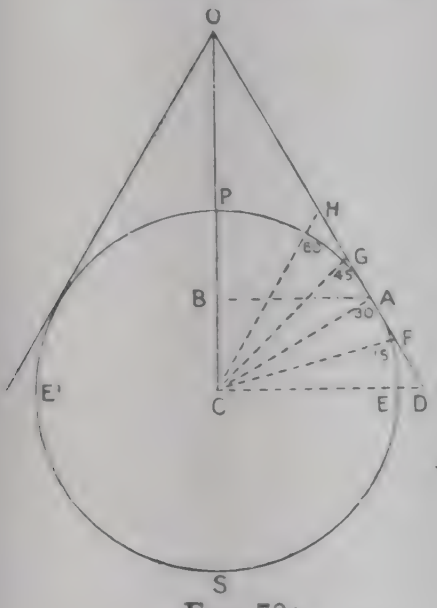


FIG. 78A.

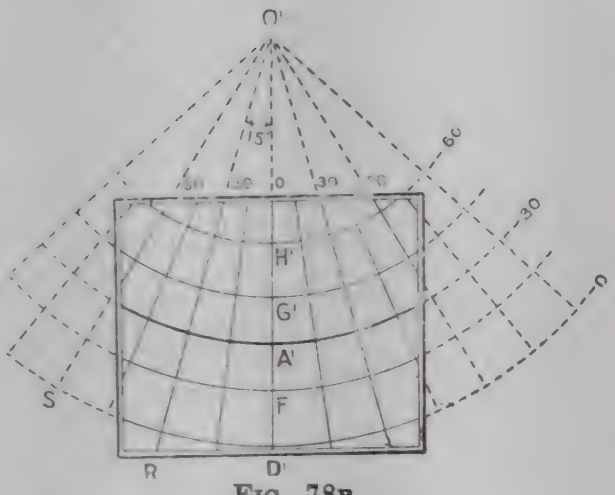


FIG. 78B.

CENTRAL CONICAL PROJECTION.

the angle BOA is 30° OA is twice AB. Thus the surface of the cone is developed into a semicircle. On this semicircle must be represented all the meridians from 0 to 360°, i.e. any angle at O^1 represents twice that angle of longitude: the angle of 15°, D^1O^1R, really represents 30° of longitude, and the line O^1R is therefore marked 30°; similarly D^1O^1S represents an angle of 60° and O^1S is marked 60°. Proceed to construct the other meridians in the same way.

The networks already treated of are real projections, but they are of little value, for they do not show distances nor directions nor shapes correctly: only one shows areas correctly, and that one greatly distorts the shapes.

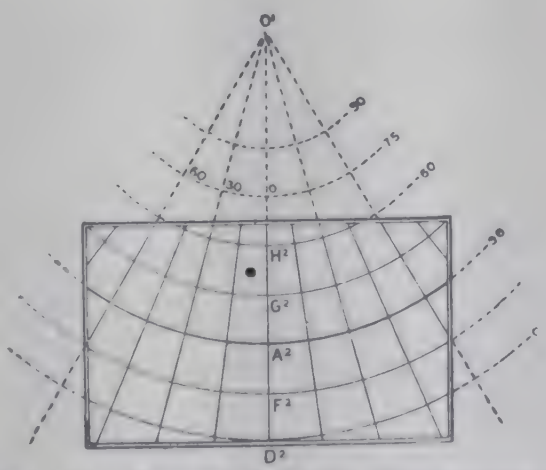


FIG. 79.—SIMPLE CONICAL PROJECTION.

The Simple Conical Projection is shown in Fig. 79, drawn for central parallel 30° and central meridian 0°. The meridians are constructed as in the last

network, but instead of having the distances between the parallels exaggerated the further they are from A, as H^1G^1, etc., the distances A^2G^2, G^2H^2, etc., are the correct distances between the parallels measured, not along AO in Fig. 78A, but along the circle itself. The parallels are then drawn as concentric circles with centre O^1 and radii OH^2, OG^2, etc. This is not really a projection at all, but is obviously more useful than the last.

The Modified Conical Equal Area Projection is shown in Fig. 80 for the same central parallel and meridian as before. The parallels of latitude are obtained as in the last, i.e., O^1A^3 is equal to OA in Fig. 78A, and the other parallels are concentric circles centre O^1 and radii such that the distances between the parallels are correct. In this network the distances *along* the parallels between successive meridians are also correct, i.e., A^3X is the correct distance in latitude 30° between two meridians 15° apart; D^3Y is the correct distance at the Equator between two meridians 15° apart. These distances in practice are obtained from tables, but they may be found geometrically. D^3Y is the part of the circle radius CE in Fig. 78A which subtends an angle of 15° at the centre; A^3X is the part of a circle radius AB which subtends an angle of 15° at its centre, and so on. This is a very useful network. It is "equal area," and parallels are their true relative lengths. It is the one used for the Ordnance Survey, 1 inch, of Scotland and Ireland, and is suitable for lands in middle latitudes generally.

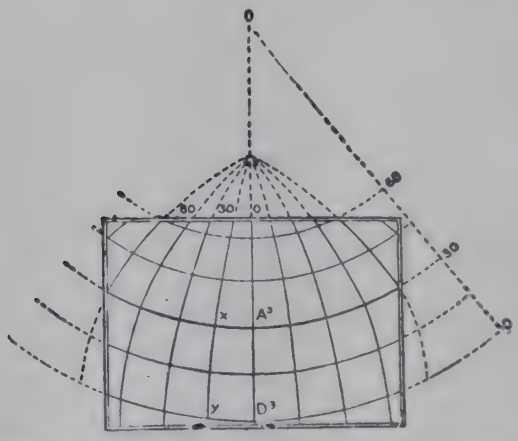


FIG. 80.—MODIFIED CONICAL EQUAL AREA PROJECTION.

The Sinusoidal Equal-Area Projection is the network obtained if we imagine the apex of the cone in the last example to become so distant that the cone becomes a cylinder touching the globe at the Equator. It

may also be constructed in the following way to show lines of latitude and longitude for every 30° on a hemisphere. Draw two lines at right angles COC^1 and ROR^1 (Fig. 81). Divide each of them into six equal parts at A, B, A^1, B^1, P, Q, P^1, Q^1. Through A, B, A^1, B^1, draw parallels to RR^1. These parallels are latitude lines. Construct a quadrant with radius XY equal to OP ; mark off angles XYL, XYM, equal to 30° and 60° respectively, drop perpendiculars LN,

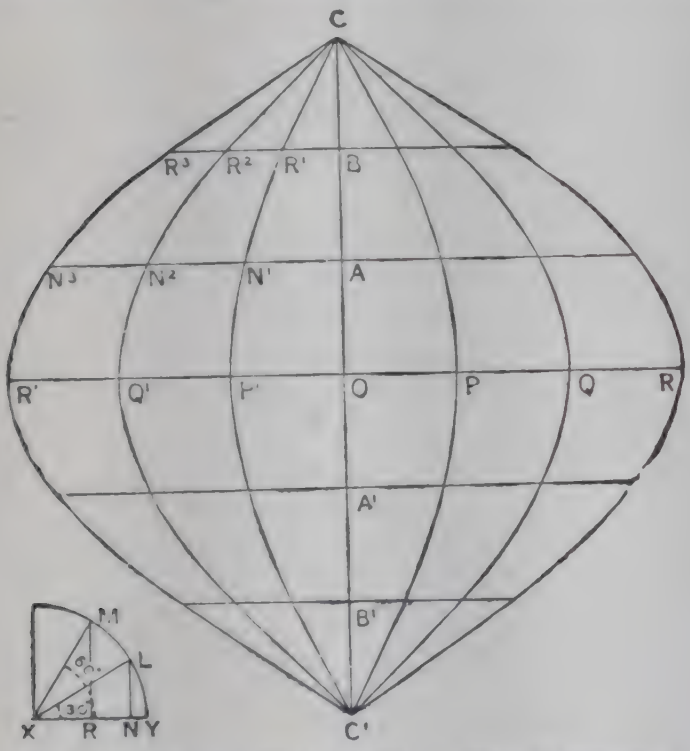


Fig. 81.—Sinusoidal Equal Area Network.

MR on XY. Mark off along the parallels through A and A^1 distances equal to XN. The points of division are at N^1, N^2, N^3. Mark off along the parallels through B and B^1 distances equal to XR. The points of division are at R^1, R^2, R^3. Join C, R^1 N^1 P^1, C, R^2 N^2 Q^1, etc. These are the meridians. Intermediate meridians may be constructed in a similar way. This projection is specially suited for the mapping of areas not far removed from the Equator.

Exercise 114.—Construct a sinusoidal equal area network suitable for a map of Africa to show meridians and parallels for every 10°

Polar Equidistant Zenithal Projection.—We have already shown how to construct a polar projection, but it is of little use because there are others which are better. One of the latter may be constructed thus : draw through any point O lines to represent the meridians radiating from the pole ; along one of these lines mark off equal distances at A, B, C, etc. ; with centre O and radii OA, OB, OC, etc., draw circles which may be labelled in any convenient way. In Fig. 82 they have been labelled for every 10°.

Exercise 115.—Draw the Polar Equidistant Projection, showing lines of latitude and longitude for every 10°. Insert the outline of the Arctic Ocean and compare it with the map on the Polar Orthographic Projection.

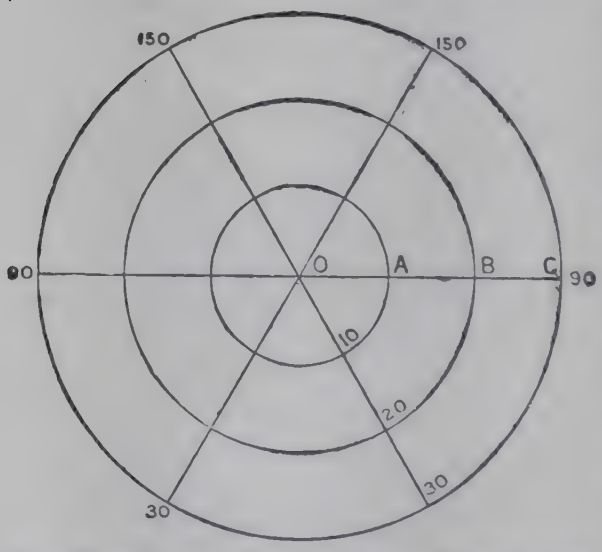


Fig. 82.—Polar Equidistant Projection.

Sometimes it is necessary to construct a map to show the whole world at once, as for example where world temperature or world rainfall has to be exhibited. Some form of cylindrical projection is suitable, such as the **Equal Area Cylindrical. Mercator's Projection** may be used, but it is not very suitable, as the poles are not shown and the relative sizes of areas are most incorrect. Mercator's map is most useful at sea, and charts are constructed on this projection because it gives the sailor the direction he must steer in order to pass from one point to another. On the map he joins the two points by a straight line, and the angle this makes with the meridian is the direction in which the ship must be steered. This does not give the shortest distance on the globe between the two points. The shapes of small areas on this network are correct, and it is by arranging that this shall be so that the network is constructed.

The calculation of the distances from the Equator at which the parallels must be placed involves rather advanced mathematics.

Homalographic Equal Area Network.—This network has the following advantages: the whole world is shown at once as an ellipse: it is equal area and lines of latitude are represented by lines parallel to the Equator. It is thus very suitable for maps which show distributions all over the globe, especially temperature, pressures, planetary winds, etc., which are arranged in belts roughly parallel to the Equator. It is used in Fig. 9 to show mean annual temperature over the world. The explanation of the construction of this network also involves rather advanced mathematics.

Exercise 116.—Look in your atlas and find what networks are used for the following maps:—The world, the eastern hemisphere, the polar regions, Russia, Switzerland, Britain, Japan, Africa, Australia, Oceania

REVISION EXERCISES

1. Explain why the scale of units attached to a map of a large continent cannot be used for measuring long distances in all directions upon that map. C. J., 1892.

2. Draw parallels of latitude and meridians for a map of the eastern hemisphere on the stereographic projection, the plane of projection passing through the meridian of Greenwich. Only the following parallels and meridians need be shown:—the Equator, and parallels of latitude for 45° N. and 45° S.; meridians for 45° E., 90° E., and 135° E. C. S., 1905.

3. What are the special advantages and disadvantages of a map on an "equal-area" projection? Mention any purposes for which you would prefer to use such a map. O. S., 1906.

4. Explain the conical projection for making maps and point out its advantages and disadvantages. C. S., 1901.

5. Describe the principle upon which a map of the world is constructed on Mercator's projection. C. J., 1901.

CHAPTER XXIII

MEASURING AREAS

We have noticed that plans and maps of small districts give us direction and distance. They give us also information as to the area of the surfaces that are measured

or surveyed. Maps of large districts do not always give either direction or distance or area correctly, so that in measuring a map you must be sure that you are working with one that gives correct results.

Exercise 117.—Consider Fig. 56. The side of each square is formed by a line representing a length of one foot, therefore each square represents a square foot. Find the area of the room of which this figure is a plan.

It is not necessary to *count* the squares one by one, as with the exception of five squares all lie within a rectangle whose length can be found by multiplying the length by the breadth.

Exercise 118.—Let ABCDE represent a plan of a field. Divide it into triangles and drop perpendiculars AF, BG, DH as shown.

The area of the triangle ABE $= \frac{AF \times BE.}{2}$ i.e., half the product of the base and the height. Find the area of the triangle in square inches in this way. Similarly, find the areas of the other two triangles BEC, and CED. Add the areas of the three triangles and you have the area of the whole figure ABCDE.

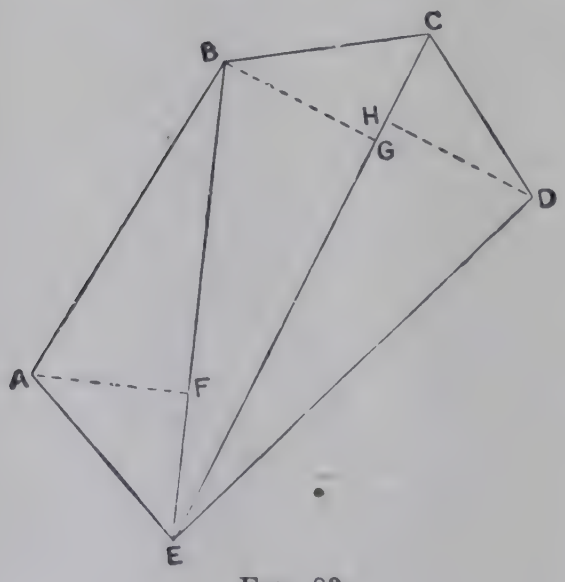


Fig. 83.

Exercise 119.—Find in this way the area of the diagrams given in Fig. 83, assuming that it is drawn on the scale of 1 inch to a hundred yards.

If a figure has irregular sides it may be divided into triangles and rectangles whose sum will give the required area approximately. In Fig. 58 the area of the triangle ABC is approximately the area of the playground. To find the area more accurately the areas of the smaller triangles may be found.

Exercise 120.—Find the area of the playground in Fig. 58. Remember that the length of AB is 375 feet.

Exercise 121.—Find the area of the field in Fig. 59.

Exercise 122.—Find the area of the three fields in Fig. 60. Another method of finding the area of a figure with irregular sides is shown in the following example.

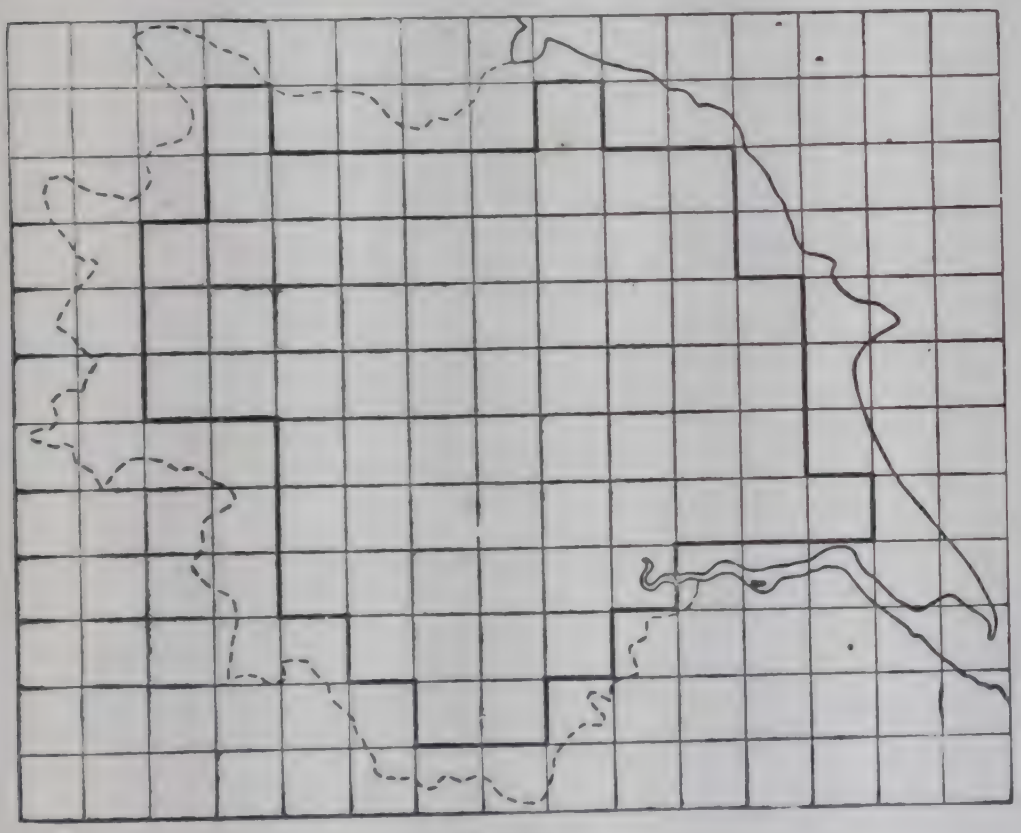


Fig. 84.

Exercise 123.—We have here a map of Yorkshire drawn on a scale of 32 miles to 1 inch. Each side of the squares shown by the fine lines is $\frac{1}{4}$ inch long and therefore represents 8 miles. The area of each square is $8 \times 8 = 64$ square miles.

The dark line that has been drawn includes all the squares that are unbroken. Count these. Next try to estimate how many complete squares would be found by the parts of the map enclosed in the broken squares. Count as one square each part which is greater than half a square and leave all parts less than half a square.

Number of unbroken squares $= x$
Number of complete squares in the broken squares $= y$

Total $= (x + y)$.

One square represents 64 square miles.

Therefore area of Yorkshire $= (x + y) \times 64$ square miles.

Compare this answer with the area given in a gazetteer or other book of reference.

Exercise 124.—Trace from your atlas the area of your own county on transparent tracing paper ruled in squares. Find its area.

Exercise 125.—Use a map on an "equal-area" projection to find the area of Africa.

CHAPTER XXIV

THE REPRESENTATION OF HEIGHTS

So far, the maps which we have drawn have given us the shapes of various boundaries, the directions of certain roads, and the relative positions of a number of objects such as trees, ponds, houses, and churches. But such maps do not show whether the ground is level or not. As a matter of fact, the ground is rarely level for any great distance. It rises and falls, sometimes forming gentle slopes, sometimes rising in rounded hills, or towering aloft in jagged and precipitous ranges. A map, to be of any great use, must show, not only direction and distance, but also how the land rises and falls. This is done in several ways.

I. Hachures.—One method of exhibiting the relief of the land is by means of lines called hachures, which show how the land slopes. Fig. 85 is a map of the Isle of Wight shaded in this way. The lines are drawn to show the direction in which a drop of water would flow downhill. Where the slope is steep the lines are drawn close together; where the slope is gentle they are drawn far apart; where the land is flat or almost flat the map is left blank. Flat areas may occur on the tops of hills or at lower levels:

FIG. 85.—HACHURED MAP OF ISLE OF WIGHT.

so that it is sometimes difficult to tell in which direction the land slopes, e.g., we must use our common sense to determine whether the slope is downward or upward from A to B. In some maps this difficulty is overcome by making the upper part of each stroke the thicker. Thus in Fig. 86 A is a hill while B is a hollow.

Ridges or valleys are represented by long white patches. In the case of narrow valleys and sharp ridges the hachures meet.

Exercise 126.—In Fig. 85 find a ridge, two or three peaks, a wide valley, and a narrow valley. What is the height of the land at A and C? Where are there steep cliffs? Where are there low shores. If one stood at A what would one see? Write a description of the view looking directly north.

FIG. 86.—HACHURES, ENLARGED.

Exercise 127.—Examine a hachured map of your own county and answer questions similar to those in the last exercise.

II. **The Layer System.**—In the layer system different colours are used to show the differences of level, all land at the same level being of the same colour. This system is employed in many atlases. It is very effective, as it at once catches the eye. Bartholomew's Reduced Survey Maps, 2 miles to the inch, are coloured in this way. Get one of these maps showing your own county.

Exercise 128.—Where is the highest land in your own county? the lowest? Give a brief description of the relief. What are the highest points in the county?

Exercise 129.—Find two roads connecting the same two

Fig. 87.—Isle of Wight.

places. Which of these two roads would give you the most free-wheeling on a bicycle?

Exercise 130.—In what directions do the rivers run? Write a description of the course of the stream or river nearest the school. How many feet does it fall in passing through the county?

Exercise 131.—Follow out the course of the railway that runs through your own town across the county. Observe whether it follows the river valleys or not and account for its course.

Contour Lines.—In Fig. 87 we have again a map

of the Isle of Wight. All the land over 300 feet is shaded and that under 300 feet is left unshaded.

Exercise 132.—What is the height of the point A? What is the height of B, of C, of D? What is the height of any point which separates the shaded and unshaded areas?

Since all the points on this line are 300 feet above sea-level this line is called the "contour line" of 300 feet.

In Fig. 88 we have the island with the 300 foot contour

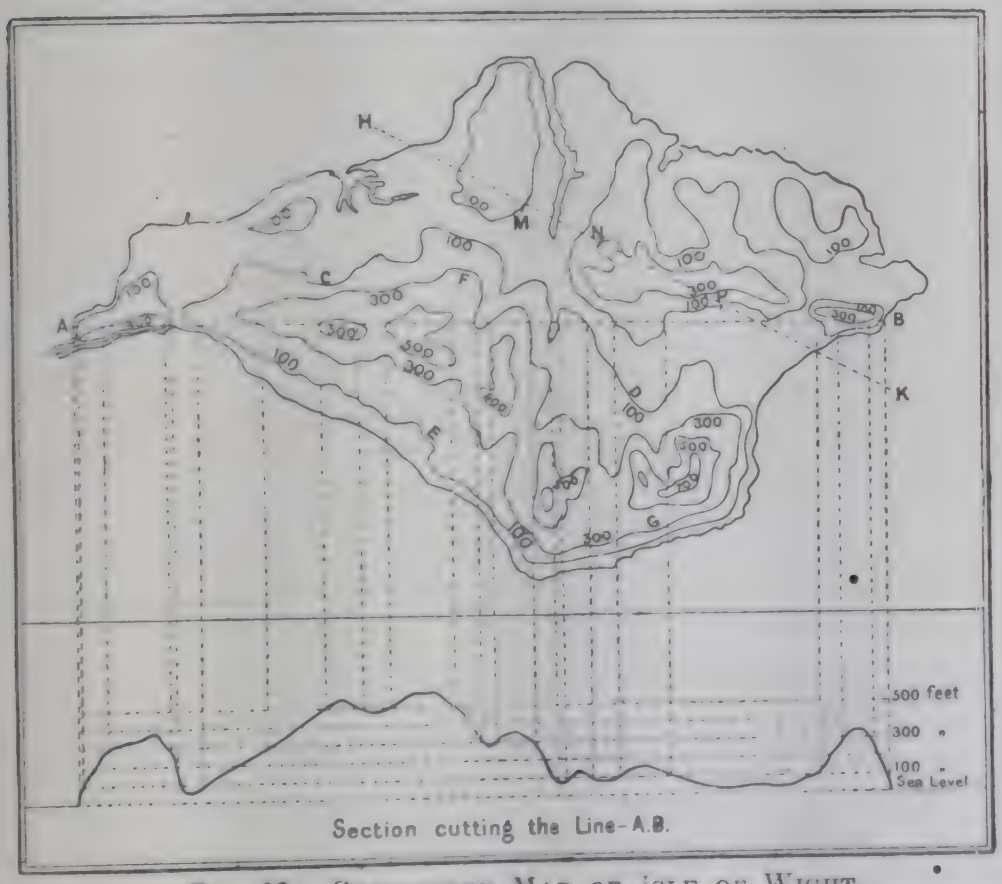


FIG. 88.—CONTOURED MAP OF ISLE OF WIGHT.

line drawn and additional contour lines inserted for 100 and 500 feet: these lines bound areas which are 100, 300 and 500 feet respectively above sea-level.

Exercise 133.—What heights are the points A, C, D, E, F, G, M, N? What is the contour line of 0 feet?

Exercise 134.—Take a potato and cut it down the middle. The part exposed by the cut shows the outline of the potato at that place. It is a **section.** When you have a contour

map you can always make a drawing which will show what the country would look like if it were cut through, and one part removed so that the other could be seen.

A method of drawing a section is shown in Fig. 88.

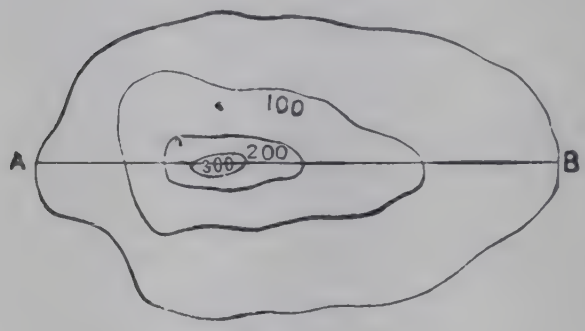


Fig. 89.

Underneath the contour map you have a scale of heights. The heights must be on a much larger scale than the scale of the map, or they will be too small to be seen. Choose a convenient **scale of** heights, and number them 100, 300, etc., to correspond with the numbers on the contour lines. Choose a point on the map at the place where the line of section cuts the contour line 100. Drop a perpendicular from this point to the 100 foot line on the scale below. Follow the section line to the next contour line, 300. Drop a perpendicular to the 300 line on the scale below, and so on. Join the points as shown in the figure. If you wish to draw a section across HK, draw a horizontal line equal to HK, erect a scale of heights, and mark the positions of M, N, P, etc., on their appropriate lines.

Exercise 135.—Copy Fig. 89 into your notebook. Draw a section along AB. What do **you notice** about the closeness of the contours and the **steepness** of the slope?

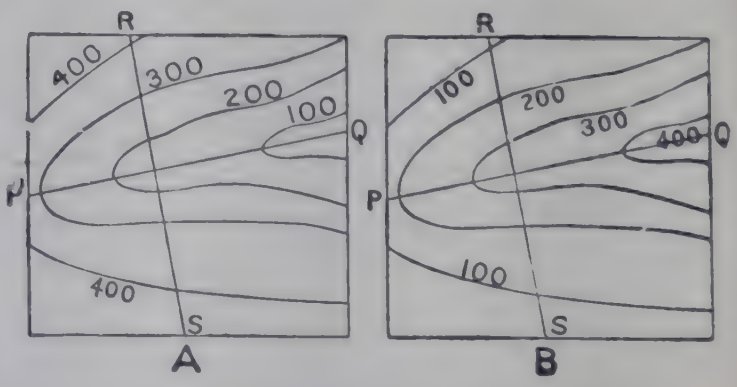


Fig. 90.

Exercise 136.—Copy the two sets of contours shown in Fig. 90. Notice that the lines are of exactly the same shape and are the same distance apart in each case. Draw

sections along PQ and RS. What differences are there in the sections? What does A represent? What does B?

Exercise 137.—Copy Fig. 91 into your notebook. Draw a section along AB. What does the diagram represent?

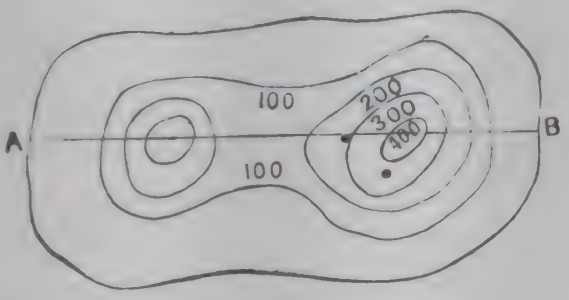


Fig. 91.

Exercise 138.—On the accompanying map (Fig. 92) the configuration of the ground is shown by contour lines at vertical intervals of 30 feet. Draw a vertical section of the country from E to F in the space provided below the map.

Exercise 139.—Study a physical map in your atlas. You will find that a certain scheme of colouring has been adopted

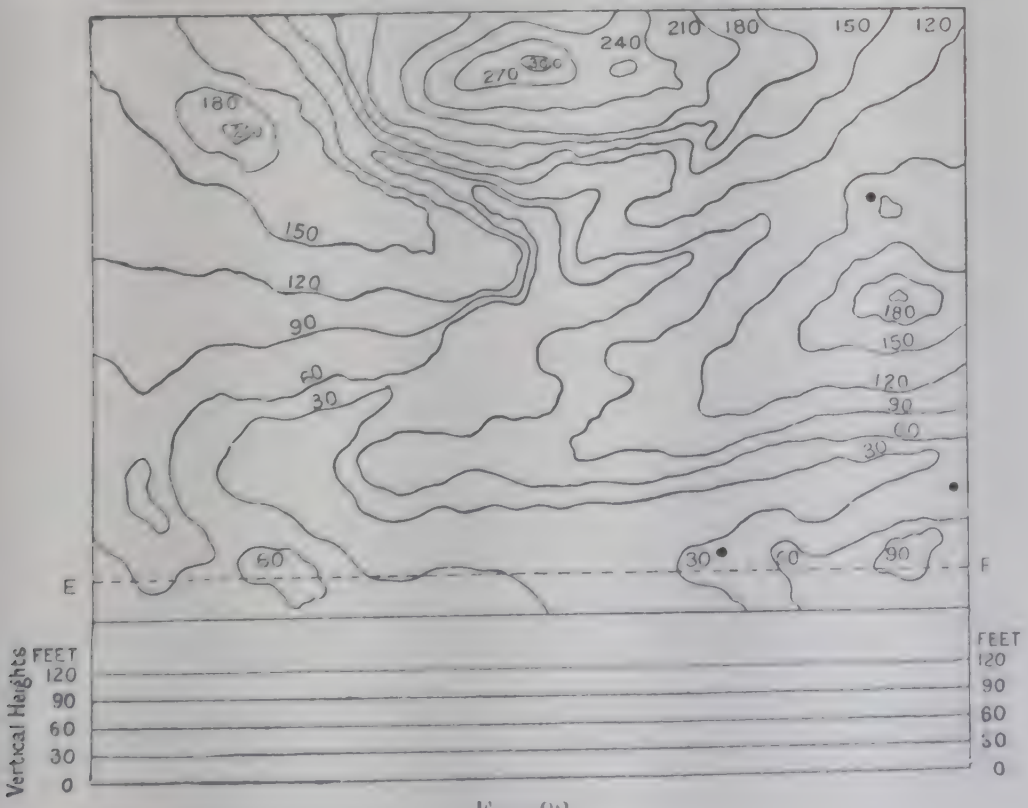


Fig. 92.

to give you the heights of the land and the depths of the water. Make a section across a certain part of the country. Draw a horizontal line on the same scale as the map. Choose a convenient scale for the heights, and rule the necessary lines. Draw on the map in your atlas a line connecting two places between which you wish to draw the section. Put a strip of paper along the line you have drawn on the

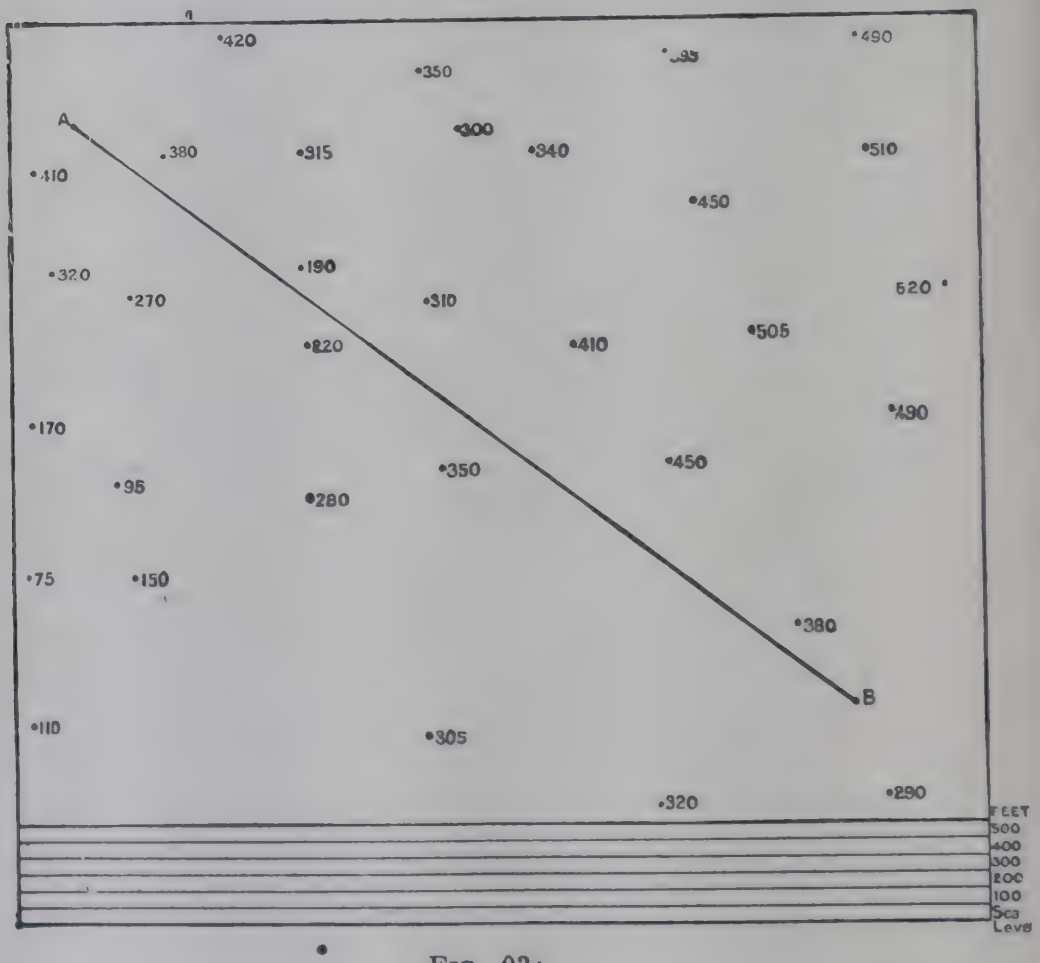


FIG. 93A.

map, and mark with pencil where each colour begins and ends. Transfer these marks to the datum-line, and then erect perpendiculars to represent the different heights. Join the points found.

In this way draw one or more sections as follows: (1) Gibraltar to Berlin; (2) New York to San Francisco; (3) Quito to Rio de Janeiro; (4) Bombay to Madras;

(5) Adelaide to Sydney; (6) Mouth of the Congo to the Mouth of the Zambesi.

The methods by which a country is surveyed in order to determine how contour lines lie, is described in the next chapter, but it may be stated here that they all depend on finding the heights of a number of points whose positions are plotted on a map. The further procedure is exemplified in the following exercise.

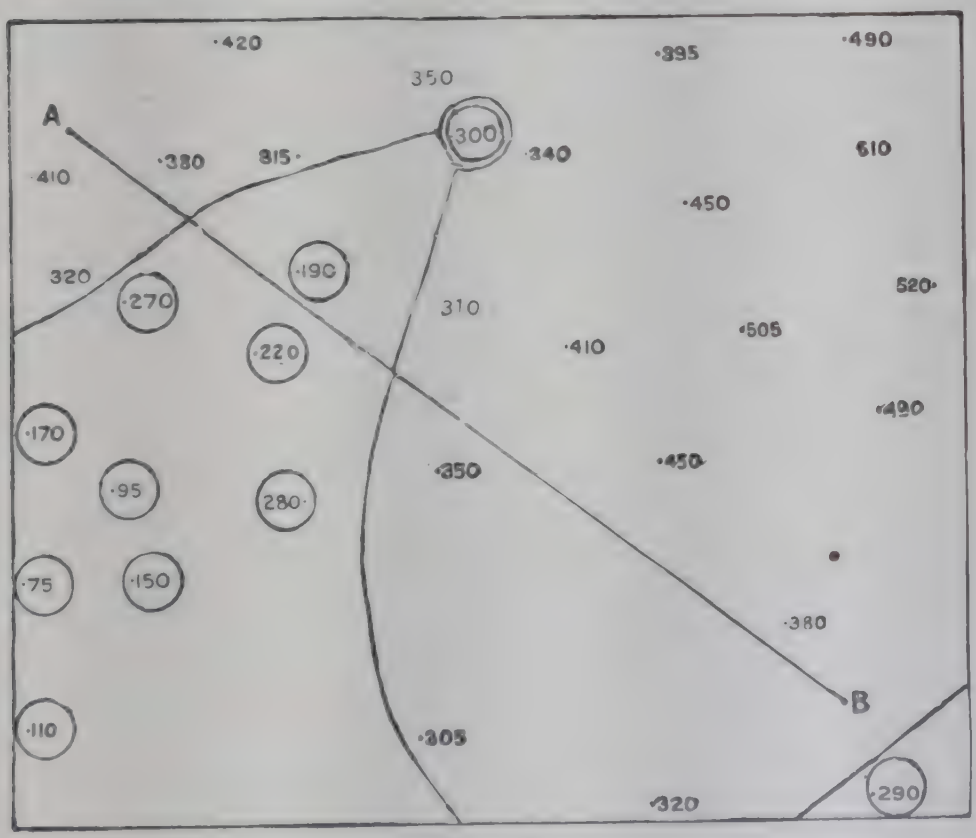


FIG. 93B.

Exercise 140.—On the accompanying map (Fig. 93A) the heights (in feet) above the sea-level are given at a number of points. Draw the contour lines at intervals of 100 feet, and in the space provided below the map draw a section along the line AB. C. S., 1904.

We have seen in Exercise 132 that the contour line of 300 feet is the line separating the land over 300 feet from the land under 300 feet. When we draw the contour of 300 feet on the map provided we must arrange then that all the heights given above 300 feet are on one side of the line and those under 300 feet are on the other. In Fig. 93B

all the points at a level less than 300 feet have been distinguished by circles drawn round them. The 300 foot contour line has then been drawn so as to separate this group from the others. There is one point distinguished by a double circle. The contour actually passes through this. On drawing the contour between two points, one under 300 feet and one over 300 feet, it should be so arranged as to pass nearer to that which differs by the less amount from 300 feet; e.g., there are two points near the centre of the map, one 280 feet, the other 350 feet; the contour is drawn nearer the 280 point. Just above this pair of points are other two, 220 and 310; here the contour is drawn much nearer the 310 foot point.

In the same way distinguish the points over 500 feet and draw the 500 foot contour line.

With a little practice it is not necessary to mark the points as has been done here: a little inspection will show where the points lie which are above or below a certain height.

Depths in the sea are represented in charts in exactly the same way as heights upon land, contours being drawn to connect all those points where the water is of the same depth.

Several very useful exercises can be set with regard to contour maps. You may construct a map from directions given, and you may deduce a number of interesting facts from a map already drawn.

Fully worked out examples of two such problems are given here to enable you to solve the exercises at the end of this chapter.

1. A hill, 1,000 feet high, slopes into the sea at an angle of about 30° on its north-east and south-east sides. To the north-west it is connected by a ridge 500 feet high at its lowest point with a conical peak 800 feet in height. To the west it descends precipitously from the summit to a height of 600 feet; thence it falls with a slope of about 45° into a river, which runs south east under the smaller peak, due south under the larger hill, and winds again to the south-east round the base of the latter, to enter the sea. Express these relations by a map with contour lines at intervals of 200 feet vertical height.

O. J., 1896.

The hill is 1,000 feet high, so the top is marked by a + and labelled 1,000 feet. The slope is 30° to the north-east

south-east, so that the horizontal distance to be shown on the map from the top of the hill to the sea-level in these circumstances is almost exactly one-third of a mile. The actual slope to the scale of 3 inches to a mile is found from the right-angled triangle XYZ. The distances from the summit to A and B therefore measured off equal to XZ. Contours are drawn for every 200 feet, so that contours of 400, 600, 800 feet and for sea-level must be shown. If we suppose

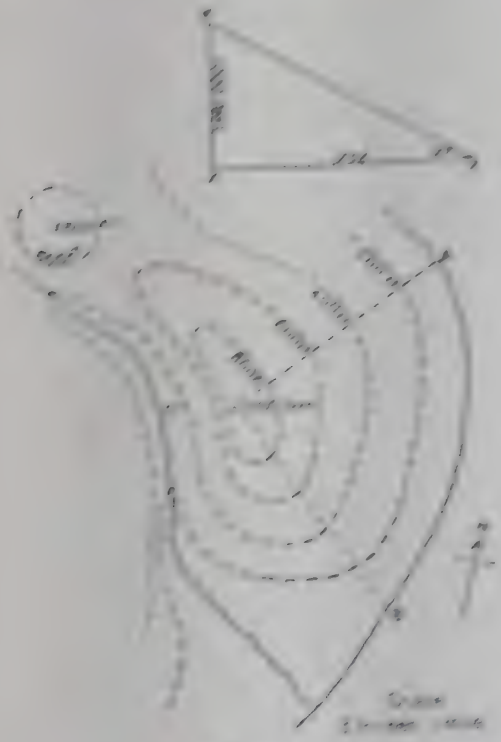


FIG. 24.

that the slope is uniform the contours are arranged at equal distances. The lines A, + B, already drawn, are divided into five equal parts and joined by curves.

We are not told at what distance from the higher hill the conical hill of 400 feet is situated, but we may suppose that it also is one-third of a mile away. Its summit is also marked by a + and labelled. The lowest point of the connecting ridge is 500 feet, so that the only complete contour round this hill is that of 600 feet. The hill is

conical, so this contour must be an exact circle. On the west of the hill the ground descends precipitously to 600 feet, i.e. the 600 foot and 800 foot contour lines must be drawn close to each other and to the summit. A river flows south-east under the smaller peak, and south under the greater peak. We are not told the distance of the river from either, but may assume that it is somewhat as in the figure and flows at a horizontal distance +C from the top of a little over 350 feet. The vertical distance of the river below the 600 foot contour must be the same as the horizontal since the slope is 45°, i.e. 350 feet. The height of C above sea-level must therefore be 250 feet. Thus the contour of 400 feet must pass between the summit and the river, but not the contour of 200 feet. The ridge between the two hills is shown by extending the contour lines of 800 feet and 600 feet from the higher hill towards the lower.

The method of treating another type of question, that referring to the description of the country represented on the map, is set forth in the solution to the first part of the following question.

2. Write a brief description of the country seen from the point A on Fig. 95 looking (*a*) north-west, (*b*) south-west. Show the route you would follow in carrying a railway from E to F. Draw a section along CD in the space provided below the map. L. J. S., 1907.

Standing at A and looking north-west we should see in front a small valley with steep sides which descends quickly to join a larger valley, with a flat floor which runs north and south. The lower part of this valley to the north would be seen over the top of a ridge on the far side of the smaller valley in front. We should look across the larger valley to rising ground on the farther side. On our extreme right we should see a ridge steep to the east but sloping gently to the west, and broken by three or four small valleys like that in front. Some distance along this ridge would be a hill of the same height as that on which we stand.

Standing at A and facing south-west we should look across a narrow steep-sided valley with a ridge on the farther side which shuts off all the view beyond to the left. On the right we should see this valley opening out into fairly

flat country. Immediately in front over the top of the ridge we should see the summit and upper slopes of an

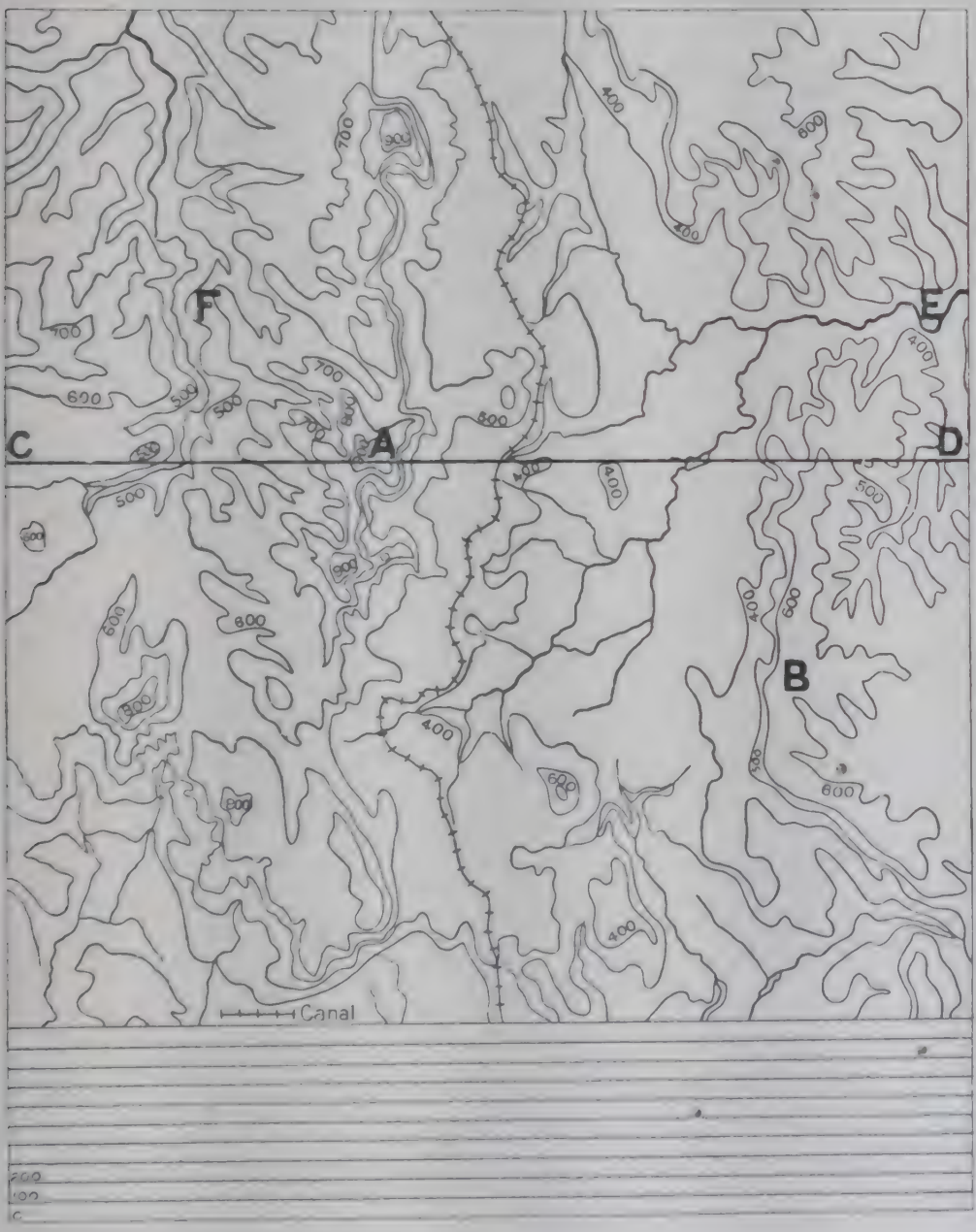


Fig. 95.

isolated hill not quite so high as that on which we stand, and to the left of it just catch a glimpse of a valley in the distance extending to the south-west

REVISION EXERCISES

1. Explain the methods of representing the relief of a country on maps. Illustrate your answer by sketch-maps, and sections of some district which you have examined. *Leaving Certif. Exam., London Univ.*, 1907.

2. If you were given a contoured map on which the summits of two hills were marked A and B, and were asked to draw a section along the straight line joining AB, how would you set about it? What is the use of a section of this kind? O. J., 1907.

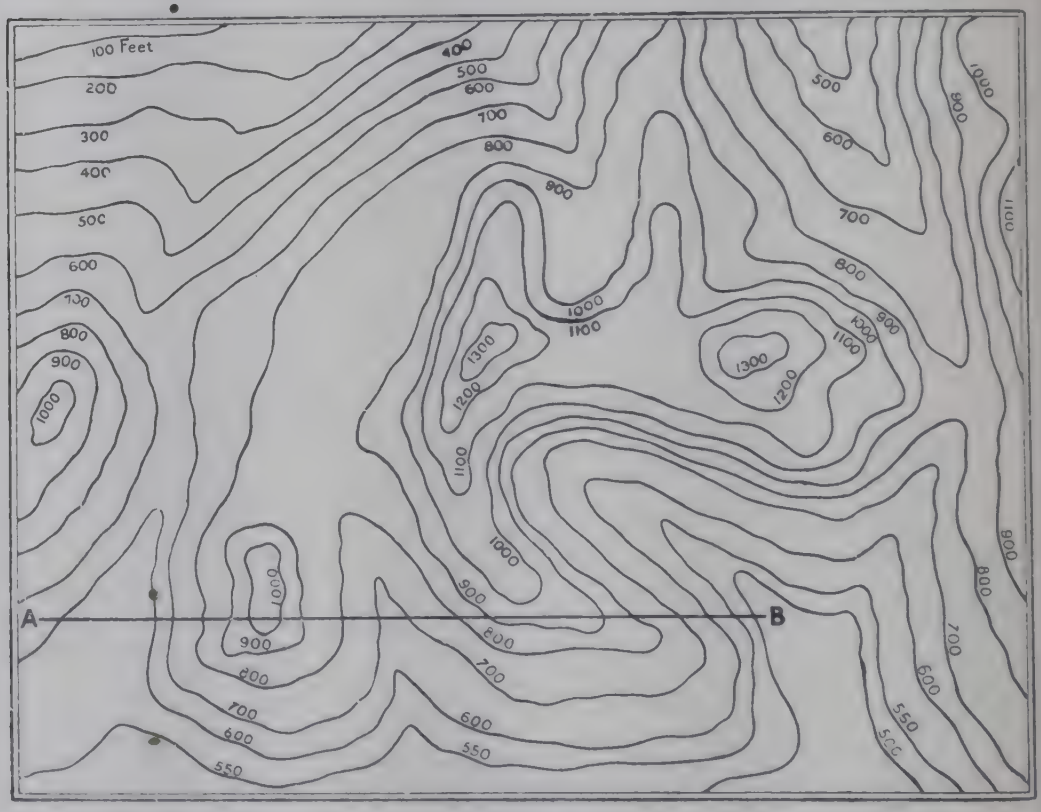


FIG. 96.

3. Draw small sketch-maps of the following, and indicate the relief by contour lines for every 100 feet: (*a*) A volcanic cone, the base of which is at an altitude of 1,000 feet, and the crater at the top 600 feet higher. (*b*) An estuary surrounded by cliffs rising to over 500 feet on all sides, and containing two rocky islands, one rising to 150 feet, and the other to 250 feet *Civil Service, Supplementary Clerks' Exam.*, 1907.

4. A ridge, 400 feet high, connects a broad topped hill, whose height is 600 feet, with a conical peak 700 feet high, situated to the south-east of the hill. The hill is indented on its west side by a steep ravine, but its other sides are of gentle declivity. The side of the peak which faces the hill is of more gradual slope than its other sides, which are steep, the south-east side being precipitous.

Express these relations by means of a map with contour lines making intervals of 100 feet vertical height. O. J., 1898.

5. A moor having a broad circular top, 1,400 feet high, descends gradually to the plain on its north and west sides, but on its east and south

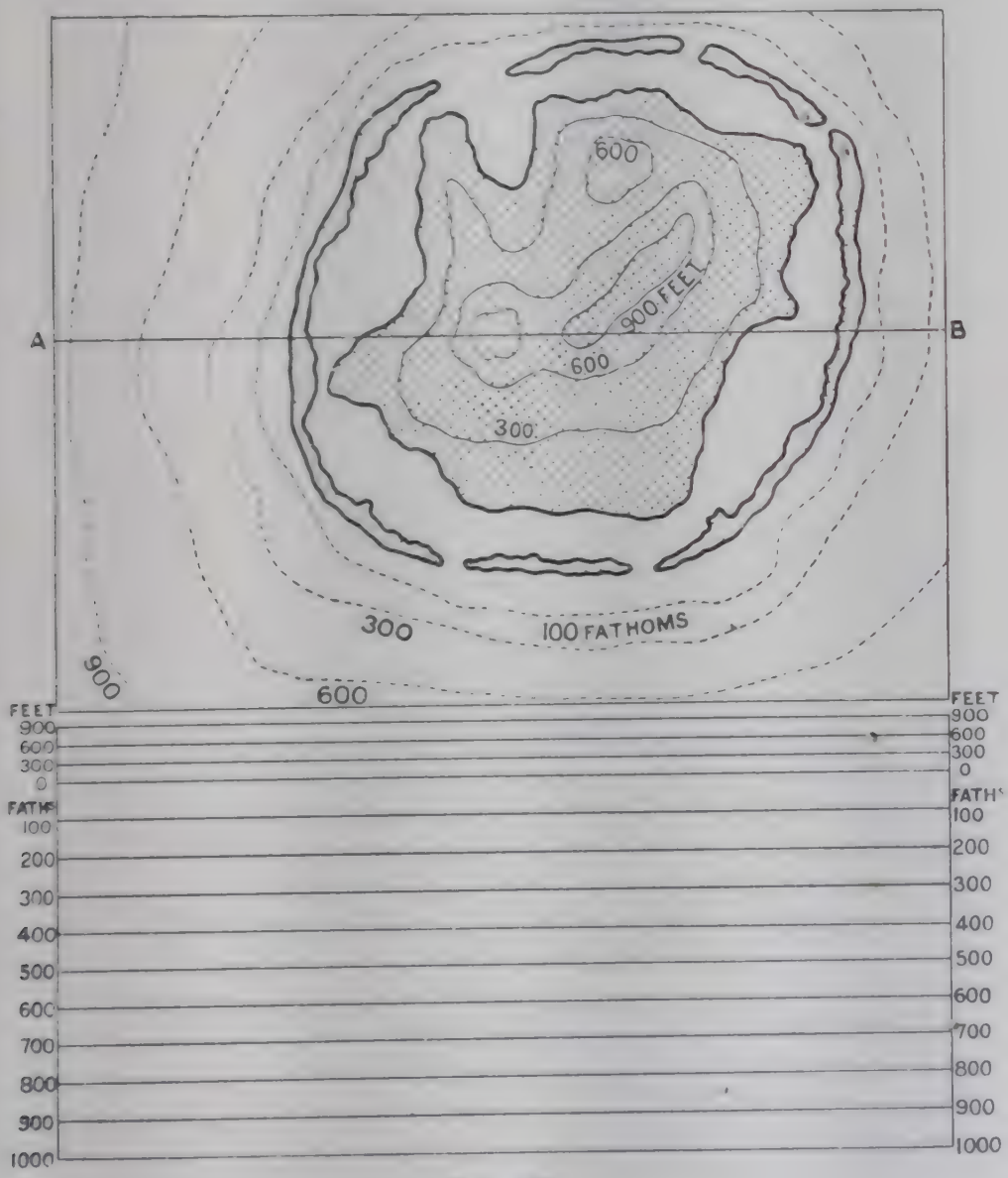


FIG. 97.

sides is indented by the valleys of two streams which rise on the moor above. The eastern valley runs east-south-east and the valley on the south side of the moor runs due south. Three spurs of the moor bound the two valleys. The eastern spur is 1,200 feet high, the south-eastern spur 1,000 feet, and the southern spur 800 feet high. The terminal slopes of the spurs are gradual, but the sides which border the valleys are very steep.

Shortly below the level of 200 feet the eastern stream bends round to the south-west and joins the southern stream to form a river flowing west. Express these relations by a map with contour lines making intervals of 200 feet vertical height. O. S., 1898.

6. On the accompanying map (Fig. 96) trace the course which you think the rivers would follow. C. J., 1900.

Draw a section from A to B.

7. In the space below the map (Fig. 97) draw the section from A to B and state what the map represents. C. J., 1905

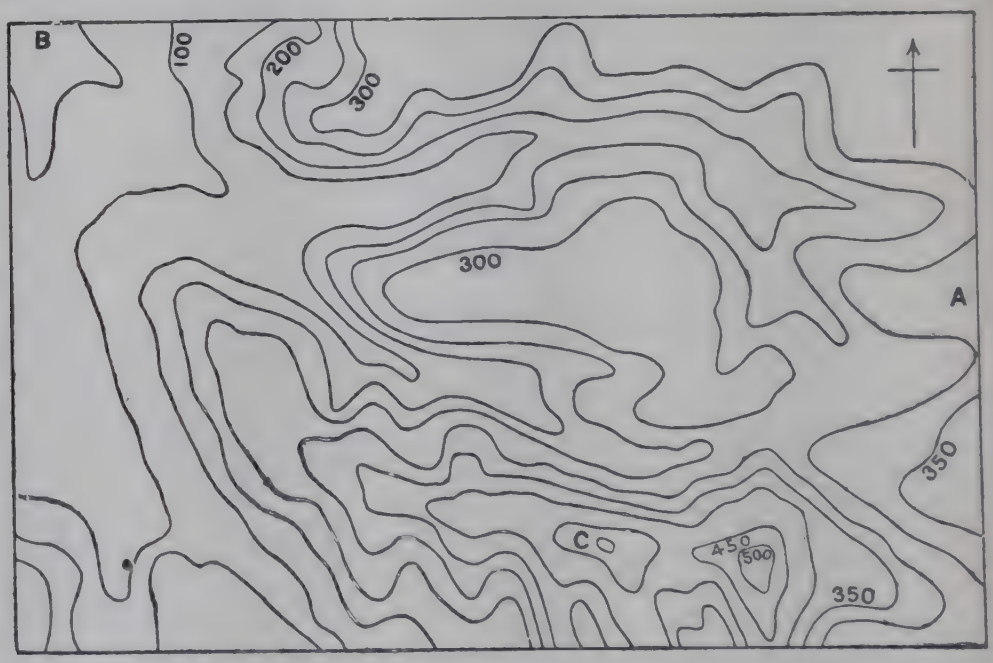


FIG. 98.

8. Give a brief description of the country shown on the accompanying contour map (Fig. 98) which is drawn on a scale of one mile to an inch.[1]

What is the approximate height of the hill C?

A river flowing between A and B is joined by three tributaries. Insert on the map the courses of the river and its tributaries, and show by an arrow the direction in which it flows. C. S., 1909.

9. Insert the rivers in the accompanying map (Fig. 99). Draw the route from B to C which would involve least climbing. Make a section from B to C in the space provided, using the same horizontal scale as that of the map, and the vertical scale shown. What are the distances between A and B and A and C? What is the area of the map.

L. J. S., 1906.

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[1] For convenience of printing the original map has been reduced in Fig. 98 to a scale of slightly less than half an inch to a mile.

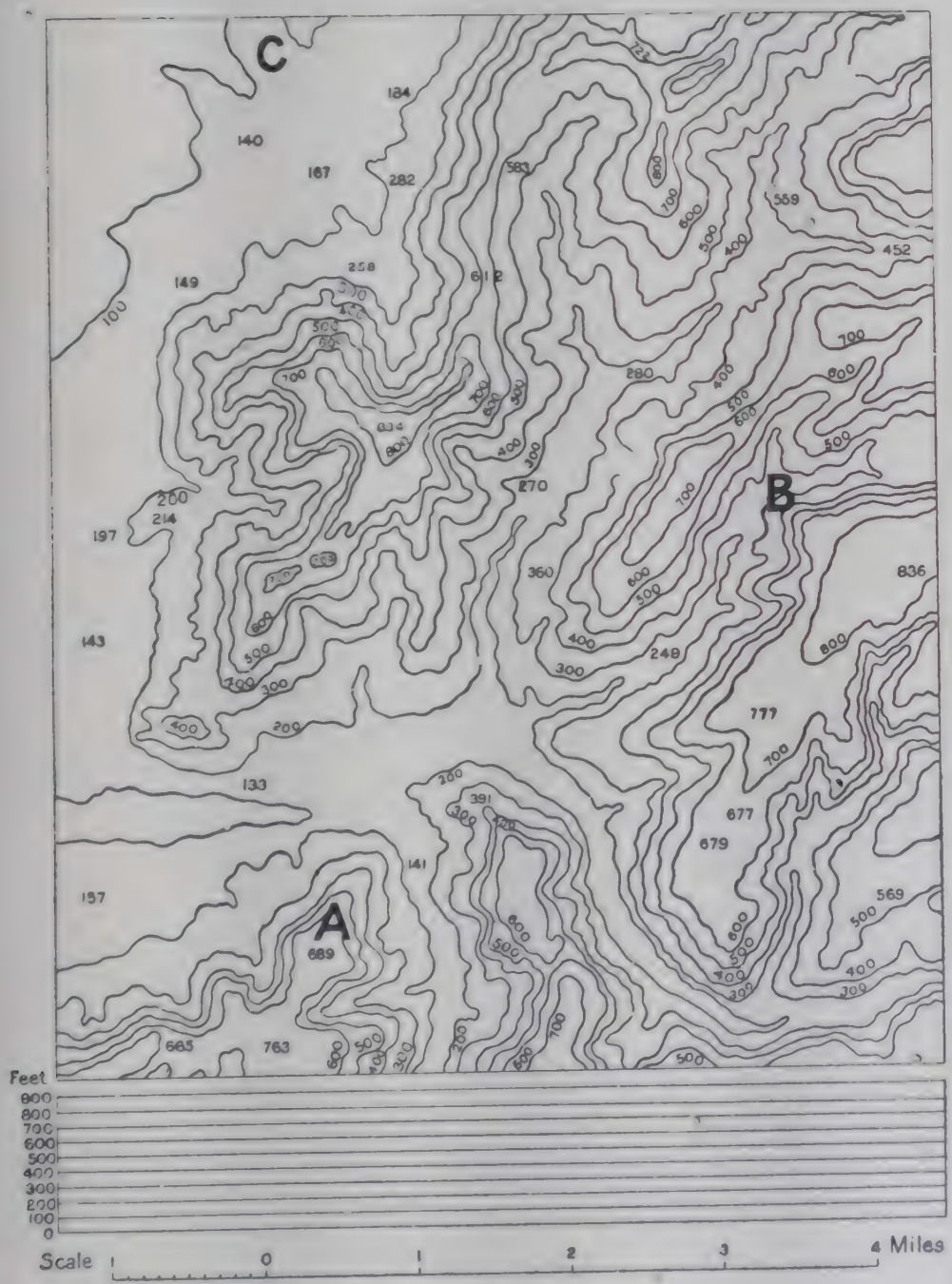
C
B
A
184
140
167
282
583
589
452
149
258
612
280
270
197
214
360
836
143
248
777
133
391
677
679
141
157
569
889
665
763
Feet
900
800
700
600
500
400
300
200
100
0
Scale
0
1
2
3
4 Miles

FIG. 99.

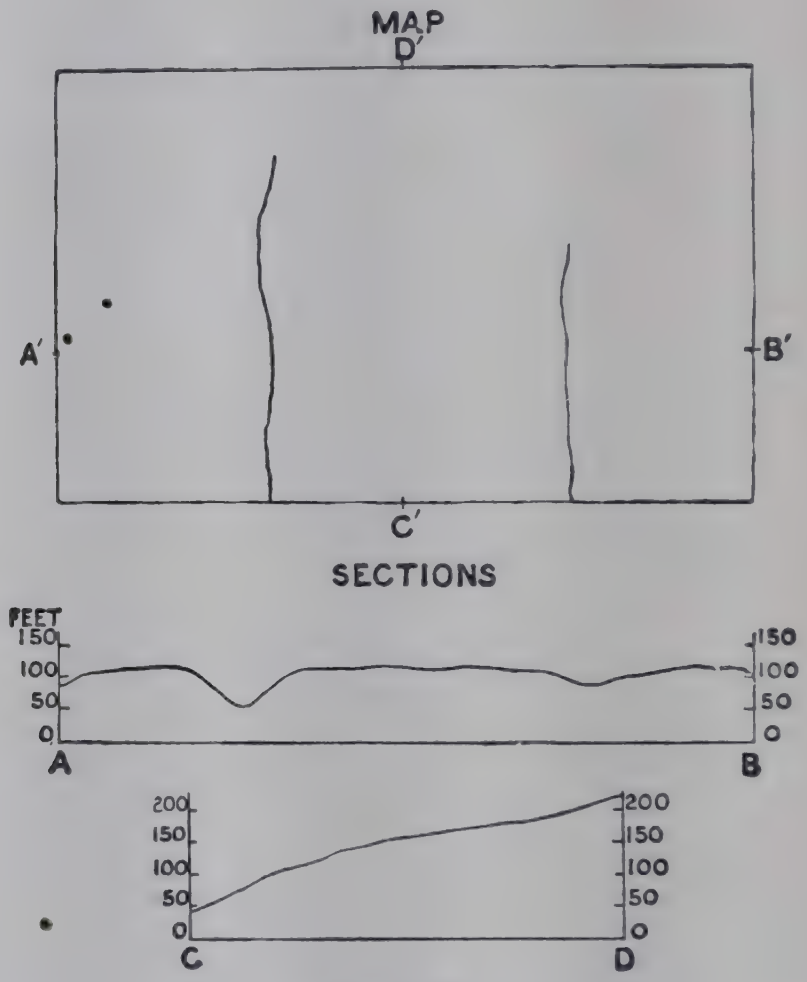

Fig. 100.

10. On the accompanying diagrams (Fig. 100) AB and CD represent sections taken respectively in the direction A′B′ and C′D′ on the map. Draw on the map the probable course of the 100 foot contour line.

C. J., 1904.

11. Represent the relief shown in Fig. 96 by hachures.

CHAPTER XXV

THE MEASUREMENT OF HEIGHTS

In the previous chapter we have studied the methods of representing differences of elevation on a map, and also the interpretation of a map upon which these differences are indicated. We have now to consider what methods

can be adopted to find the heights of the various points that are joined by the contour lines.

1. **Height found by the Barometer.**—The barometer measures the pressure of the air (see Part I. Chap. VI). In a mercury barometer this is given by the height of mercury supported by the pressure of the air. As you ascend a hill the pressure decreases and the mercury falls. It falls about $\frac{1}{10}$ inch for every 91 feet of ascent. A mercury barometer is not a very convenient instrument to carry up and down a mountain, so another instrument called an **aneroid barometer**[1] is used. In this instrument the air presses on a thin metal case, and a dial hand outside registers the pressure in inches.

FIG. 101.—ANEROID BAROMETER.

Exercise 141.—If there be any hills of decent height near the school ascend one of these and find its height by means of an aneroid barometer.

2. **Height found by the Thermometer.**—When we heat water, some portion of it is turned into vapour. When the water is hot enough this vapour passes away rapidly, and the water makes a bubbling noise. At such a time the water is said to boil. Now, boiling only takes place when the tension of the aqueous vapour is equal to the pressure of the air upon the surface of the water. If you boil water at the sea-level, you will see that boiling occurs at about 212° F. At this temperature the aqueous vapour is strong enough to overcome the downward pressure of the air. If we go up a hill until we have ascended 520 feet, and then boil the water again, we shall find its temperature is about 211° F.

In the highest parts of Himalayas the water would boil at about 180° F. For moderate heights the following rule gives rough results: *Find the temperature at which the water boils and subtract this from* 212°. *Multiply the difference by* 530 *and you have the height in feet.*

[1] A good cheap aneroid barometer is supplied by G. Philip & Son (see p. 161).

3. Height found by the Clinometer.[1]—A simple clinometer consists of a protractor, graduated as shown in the figure, and a plumb line. Sight a distant object along PQ. If the object be on the same level as your eye the plumb-line will hang at 0°. If the object be above or below your eye, the plumb-line will indicate the angle of elevation or depression, as the case may be.

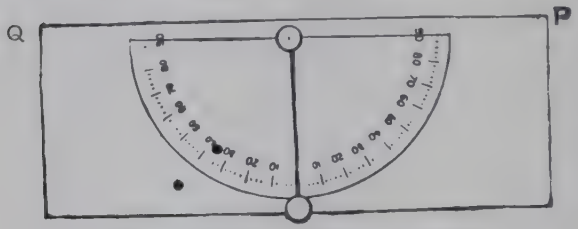

FIG. 102.—A CLINOMETER.

Suppose that BC (Fig. 103) represents the side of a hill sloping to C, and that the observer is at B. Suppose that contour lines are drawn through B and through C. Then AB is called the Vertical Interval between the two contours. It is written "V.I." and is usually expressed in **feet**. If you find on a map a note, "Contours at 50 feet V.I.," this means that any two successive contours are separated by a vertical interval of 50 feet. The distance AC is called the Horizontal Equivalent. It is written H.E., and usually expressed in **yards**. If you know both, you know the angle of the slope. On a hill-side you can find with the clinometer, the angle of the slope and the length of the slope, but you cannot get inside the hill to measure either the vertical interval or the horizontal equivalent. For moderate slopes there is not much difference between the lengths BC and AC. By measuring from B to C you get practically the length AC, and so you could find AB. With every clinometer you are provided with a "Table

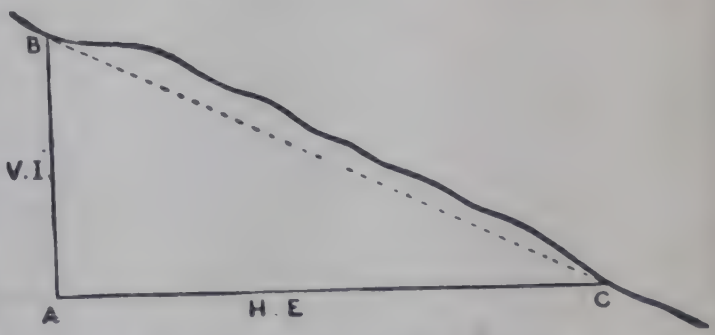

FIG 103.—"V.I." AND "H.E."

[1] A very suitable clinometer is supplied by G. Philip & Son (see p. 161).

of Horizontal Equivalents for 20 feet Vertical Intervals." Such a table is given below for reference. The use of the table will be shown presently.

Degrees.	Yards	Degrees.	Yards.
1	382	16	23
2	191	17	22
3	129	18	21
4	95	19	19
5	76	20	18
6	63	21	17
7	54	22, 23	16
8	47	24	15
9	42	25, 26	14
10	38	27	13
11	34	28, 29	12
12	31	30	11
13	29		
14	27		
15	25		

To mark Contours on a Map.—Take a map drawn on a scale of 6 inches to the mile, and go to the top of the hill you have chosen. Select a convenient starting-point. By the aid of the clinometer, find another point on the same level as far away as you can. Pace the distance. (N.B. Before setting out make 100 paces. Measure the total distance paced, and so find the length of one of your paces. Do this several times, till you feel you have got a fairly accurate and constant result). As you go towards B, sketch in the contour. If you go over a slight rise curve the line away from AB outwards from the hill. If you go down a slight hollow bend the curve inwards towards the hill. Judge all these small curves with the eye. When you get to B find a point C on the same level as B and traverse up to it in the way explained. Do this all round the hill, or else as far as you think necessary. In this way you draw the first contour line.

Now select some prominent object at E, and plot the line you mean to follow from A to E. You can take its

direction with a compass, but the map has usually enough detail on it to enable you to put in the line by eye. Such a line is called a **section line.** Observe the slope with the clinometer. Suppose that this is 18°. Look in the table of horizontal equivalents and you will see 21 yards opposite 18°. That means that if you walk 21 yards down the slope you will have descended a vertical interval of 20

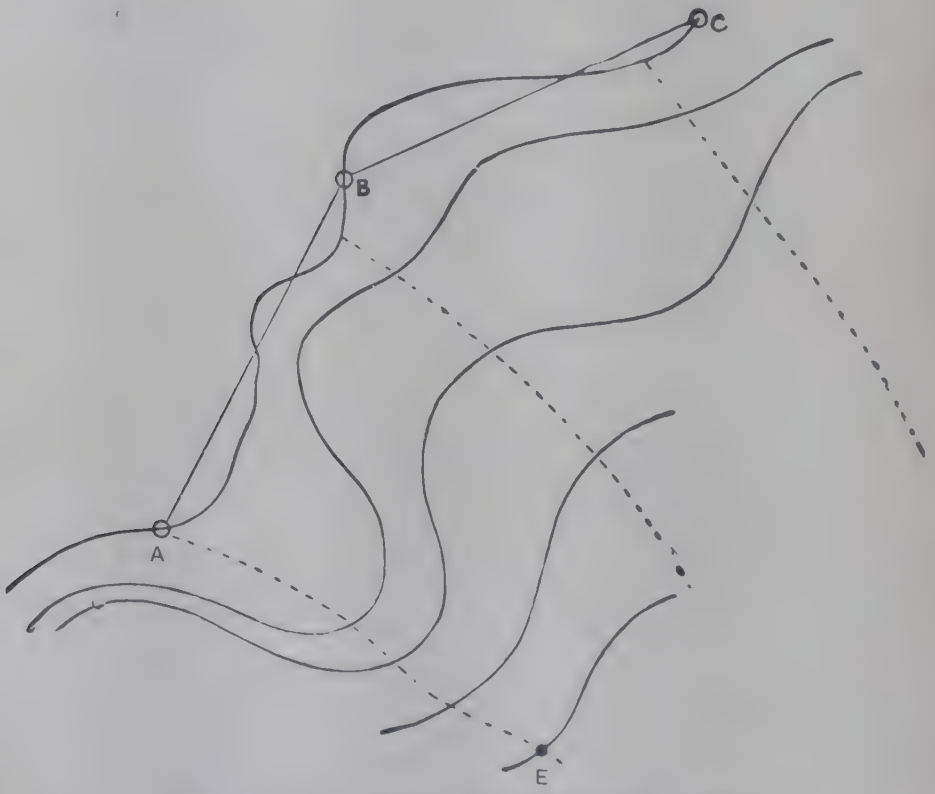

FIG. 104.—TO MARK CONTOURS ON A MAP.

feet. Pace 21 yards down the slope. Stop. Measure off 21 yards on your scale and put in another contour. Look down the slope again. Suppose this angle is 14°. The H.E. for this is 27 yards. Pace 27 yards. Stop. Measure off 27 yards on your scale and put in another contour. Go on in this way till you reach the bottom of the line.

Lay down another section line and mark contour points as before. Choose as few section lines as you can, consistent with reasonable accuracy. When there are several hills, walk along the watersheds. Every time you mark the position of a contour, face the hill, hold the map to

correspond with the ground, and trace the contour to right and left by the eye as far as you can see.

By adopting the above procedure you can draw contour lines at vertical intervals of 20 feet. But these do not give you the real height of any point. If you can find the height of one of the contour lines above sea-level with the aneroid barometer, you will then know the height of every place on the map. The level with reference to which heights are measured is called a **datum**, or **datum-line**, or **level.** You will find it most convenient to consider sea-level as the datum-line.

4. **Height found by the Theodolite.** — In your atlas and elsewhere you will find the heights given of mountains which, like Mount Everest, have never been climbed. Their heights have been determined by means of a theodolite. An idea of the method will be gained from the following exercises.

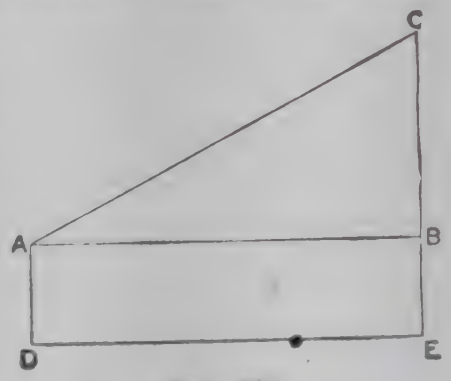

FIG. 105.

Exercise 142.—To find the height of one of the school walls by means of the clinometer.

Let the wall be CE. Measure a line on the level ground at right angles to the wall. Let this be DE. Mark on the wall EB equal to AD the height of your eye; stand at D and sight the point B with the clinometer; the plumb-line should hang at 0°. Then sight the top of the wall E and measure the angle BAC.

We have now the length AB (= DE), and the angle BAC, and ABC (a right angle). Draw the figure ABC to some convenient scale and find the height of CB. Add to this the height BE, and you have the height of the wall.

Exercise 143.—To find the height of an object whose base is inaccessible, say some conspicuous object, such as a church tower or a tall chimney, outside the school playground. AD represents the height of the church tower. Lay down a line BC in the playground. At the end B determine the angle DBA. Go to C and there measure the angle DCA.

Measure also BC. Draw BC to scale and complete the figure. Measure AD.

Exercise 144.—A flagstaff is 60 feet high. From where I stand, the angle of elevation of the top is 15°. How far am I from the staff ?

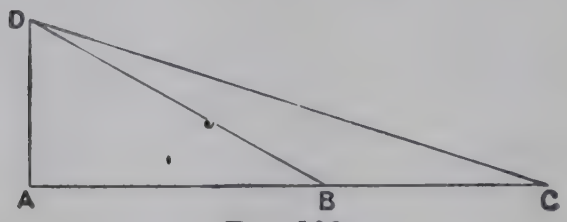

Fig. 106.

Exercise 145.—A man at sea sees a lighthouse on a rock. He is 120 yards from the foot of the rock. The angle of elevation of the foot of the tower at this place is 14°. He goes 120 yards further out to sea, and then he finds that the angle of elevation of the top of the tower is 14°. What is the height of the tower ?

Heights of mountains are found in a similar way by means of the theodolite. In Fig. 69 the instrument is seen to have not only a horizontal scale of degrees by which azimuth or the horizontal angle is measured, but also a vertical scale V by means of which altitude or the vertical angle is measured. Exceedingly small angles may be measured and heights calculated.

Height by a Level.—Construct a level as in Fig. 107 This consists of (i) a tripod A, which may be an old camera stand. To this is attached by a screw (ii) a piece of wood BC, 30 inches by 1 inch, with two circular holes, one at each end, to receive (iii) the essential part of the instrument, two glass tubes DE, 1 inch in diameter, connected by an india-rubber tube.

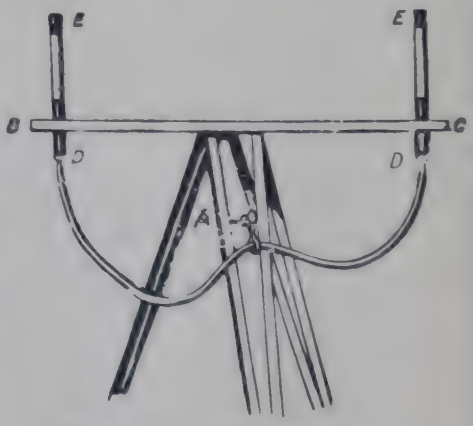

Fig. 107 -Water Level.

The connections at D are india-rubber stoppers, bored to receive small glass tubes, on which the india-rubber tube is slipped. EE are two corks, with small holes bored in them to allow of free communication with the air. A clip on the india-rubber tube allows of the level being carried

from place to place without any danger of the liquid being allowed to run out. Water coloured with ink or in any other way is passed into DE and finds its level.

Exercise 146.—Look at a copy of the 25 inch Ordnance Survey Map of the school district and note where the letters B.M., standing for Bench Mark, are printed beside a number and the sign of the "broad arrow" thus ⅄. Go to the spot and you will find the mark of the broad arrow cut on a wall with a line above it. The height in feet above sea-level of the centre of the line is given in feet by the number on the map. Measure the distance from the ground of this mark. What is the height of the ground above sea-level ?

Exercise 147.—Mark off feet and inches on a 7 foot pole. Let one pupil stand this pole on the ground whose height you have found. Set up the level a convenient distance away and direct it towards the pole. Place your eye E, so that in looking from one tube to the other the coloured surfaces are on a line. Notice what is the height on the pole immediately behind either surface. Move the pole some distance away and note the new height read on it. What is the height of the ground on which it stands.

FIG. 108.

Exercise 148.—Place the pole again beside the Bench Mark and note the reading. Move the pole to some other point so that the reading is the same as before. What is the height above sea-level of this point ?

Exercise 149.—Go to a Bench Mark where the slope is fairly steep : find the height of the ground. Place the pole on the ground and read the height as before. Let the pole be removed till the reading is 2 feet lower on the pole. What is the height of this point. Measure, by means of the chain, the distance of this point from the Bench Mark. Plot the corresponding distance on the 25 inch map and mark the height on the map. This is a new point whose height you know. You can now use this point to find the height of others.

Exercise 150.—Find the heights of points along a road and plot them on a map.

Exercise 151.—Find the height above sea-level of your class-room floor by levelling from the nearest Bench Mark.

Exercise 152.—Find the height above sea-level of the reservoir of your barometer so that you can make the necessary correction for height.

A more accurate form of level is used by surveyors. It is similar to a theodolite, but it has no vertical circle and can be rotated only horizontally. By its means are

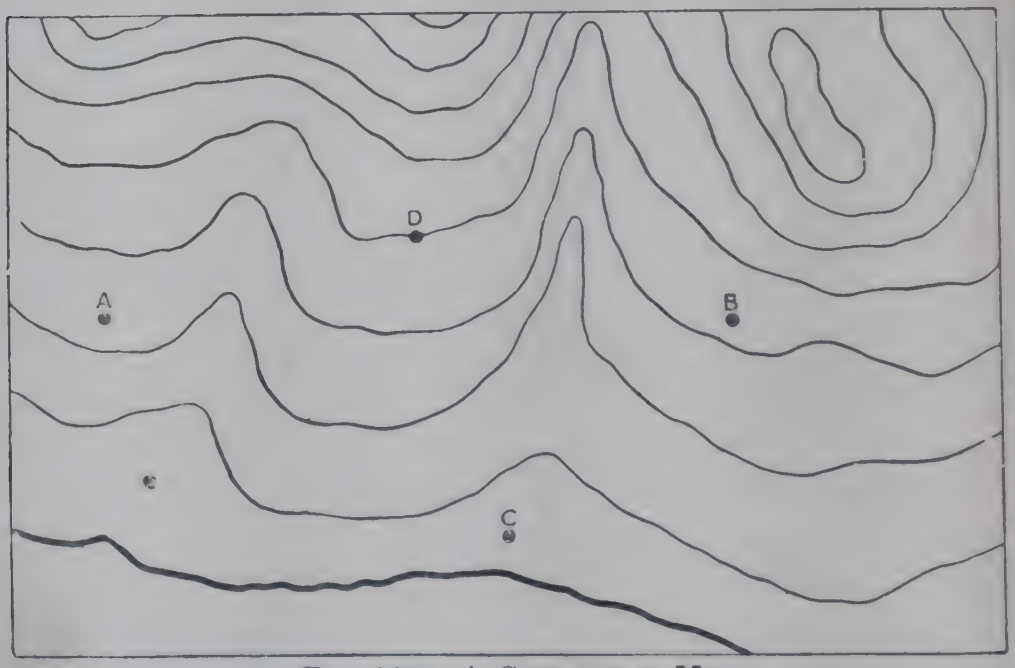

Fig. 109.—A Contoured Map.

found the heights of the Bench Marks, plotted on maps. Good levelling with such an instrument gives an error of not more than an inch in a mile. The error becomes less proportionately with the distance levelled. In a hundred miles the error should not be more than a foot.

REVISION EXERCISES

1. Fig. 109 is a contoured map. Mark on it the route with the smallest slope between the points A and B. At the spot C, which is 20 feet above sea-level, the barometer stands at 30 inches. At the same time the barometer at D stands at 29·8 inches. Find the height of D above sea-level. C. J., 1903.

2. Explain exactly in what way a flat map misrepresents distances. How is relief best shown on a map? *L.C.C. Intermediate*, 1911.

CHAPTER XXVI

ORDNANCE MAPS

THE British Government publishes Ordnance Maps on scales of 1 inch to the mile, 6 inches to the mile, and 25 inches to the mile. City and town maps are published on scales of 5 feet to a mile and 10 feet to a mile. They are obtainable from the Director General, Ordnance Survey Offices, Southampton,* and cost on an average about 6*d.* each, if ordered in numbers for school use only, though prices vary according to the number ordered and the size of the map.

Those most suitable for school work are:—

(1) For the **school district**, on the scale of 25 inches to the mile (strictly 25·344 inches to the mile).

(2) For the **environs of the school**, on the scale of 6 inches to the mile.

(3) For the **county**, on the scale of 1 inch to the mile.

If only one kind of map is to be purchased then the one on the scale of 1 inch to the mile is to be preferred.

The "25 inch map" shows boundaries and areas of fields, also levels and bench marks, but no contours.

The "6 inch" map is the largest scale showing contours. On this map areas are not shown. Both the above are published in black only.

The "one inch" map is issued in four forms:—

(i) Popular Edition with colours.
(ii) Outline Edition—water blue, contours red.
(iii) Fully coloured Edition (hachured).†
(iv) Engraved black Outline Series (small sheet).

All Ordnance Maps are printed with the north to the top of the map. They contain a number of signs, some of

*Complete information will be found in the following publications issued by the Department and supplied by George Philip & Son, Ltd., 32 Fleet Street, London, E.C. 4.

(a) Catalogue of Maps and other publications of the Ordnance Survey 1/2 post free. (b) A Description of the Ordnance Survey Methods of Surveying, Levelling, Scales and Conventional Signs 1/2 post free, with specimens. (c) A Description of the Ordnance Survey Large Scale Maps; 3*d.* post free, with specimens.

†This sheet is being discontinued as sheets go out of print.

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which are shown in Fig. 110, and a number of letters, the most common of which are :—

B., Bridge, Box.
B.M., Bench Mark.
B.R., Bridle Road.
Ch., Church.
Fm., Farm.
Fn., Fountain.
F.B., Foot Bridge.
F.P., Foot Path, Fire Plug.
F.S., Flagstaff.
Gdns., Gardens.
G.P., Guide Post.
H.W.M., High Water Mark.
L.B., Letter Box.
Liby., Library.
L.W.M., Low Water Mark.
M., Mile, Mooring.
M.P., Mile Post, Mooring Post.
M.S., Mile Stone.
P.H., Public House.
P.O., Post Office.
R., Railway.
R.C., Roman Catholic.
S.B., Signal Box.
Sch., School.
S.L., Signal Lamp.
S.P., Signal Post.
Sta., Station.
W. Well, Water.
W.P., Water Plug.

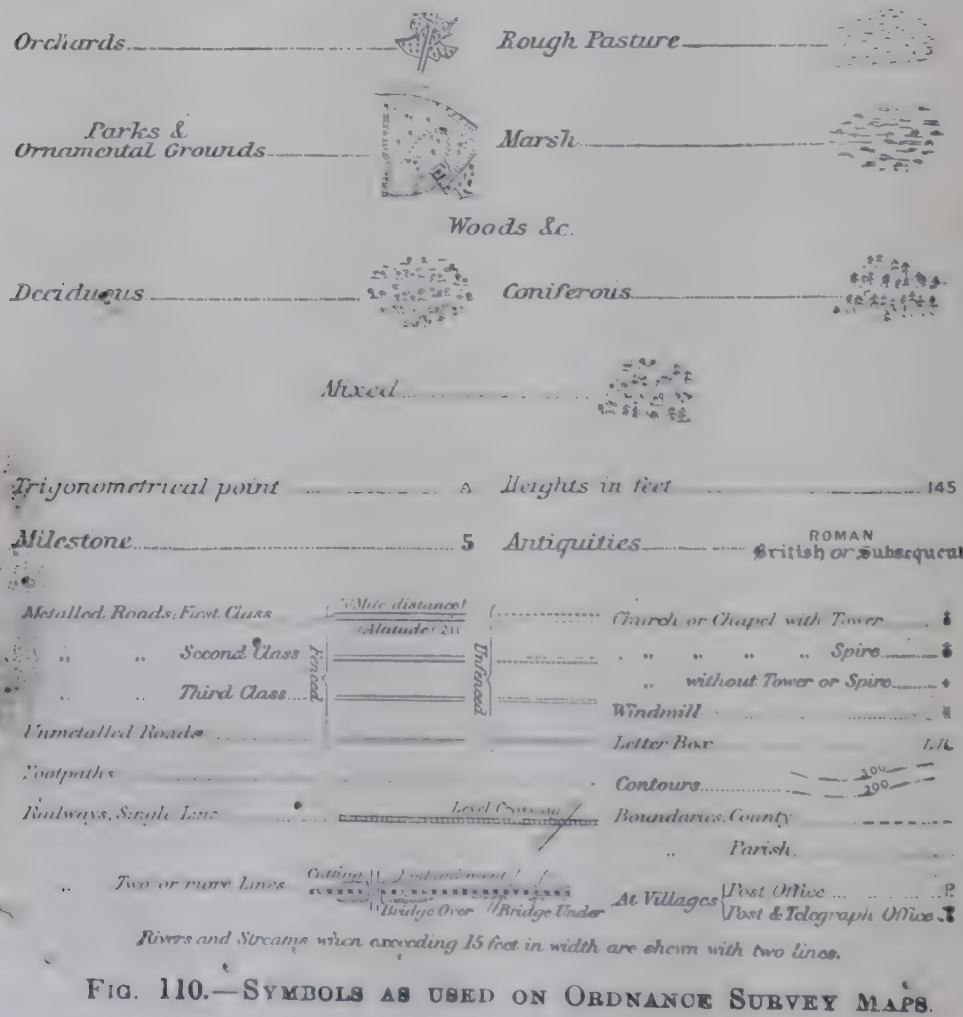

FIG. 110.—SYMBOLS AS USED ON ORDNANCE SURVEY MAPS.

There are so many types of country, that it is difficult to choose examples for reproduction. The best way to learn the use of these maps is to study those of the home district. The following exercises cannot all be worked out on the map of any one district, but all those that are possible on the maps of the home area should certainly be attempted.

The Twenty-five Inch Map.

Exercise 153.—What is the area of this map? What is the highest point on it? Choose any six places on the map and say in what direction they lie from the school. What are their distances from the school measured in a straight line? Which is the easiest bicycling route between the school and each of these places?

Exercise 154.—What is the length of the main road? (Lay a piece of thread carefully along the route, then pull it out straight and measure with a ruler). What is the breadth of the main road at three or four given points? Draw a section to show the slope of the road between two given points. What do the numbers along the road indicate?

Exercise 155.—Is the railway line through your town single or double? How far is it from the school? What length of it is shown on the map? Is it single or double? Are there any means of shunting wagons from one line to another. How is the railway crossed at various points? Where are there embankments or cuttings? What do the symbols S.P. mean? What are the distances between them?

Exercise 156.—What streams or rivers are shown? What is the length of the chief one? What is its breadth at three given places? In what directions do the streams flow? Where are there bridges?

Exercise 157.—Find on the map places where there are numerals printed in heavy type with thinner ones underneath them, e.g., $\frac{82}{1{\cdot}607}$. This means that in the survey of the district the piece of ground in question is numbered 82 and has an area of 1·607 acres. Make a list of six or seven of these places; give their areas; say whether the land

is pasture-land or woodland ; in the latter case say what kind of woodland.

Exercise 158.—Make a list of all the abbreviations you can find and give their meanings.

The Six Inch Map.

Exercise 159.—Give the length, breadth, and area of the map. In what directions do six given towns or villages lie with regard to your own town ? How far are they away (*a*) as the crow flies, (*b*) by road ?

Exercise 160.—Measure the lengths of one or two important roads. Draw a section to show the rise and fall of the main road. How do you reach the main road from the school ? Where does the main road lead to ?

Exercise 161.—What rivers are shown ? Give the length and direction of the chief one ? Find the symbol F.B. near one of these streams. What does it mean ? How many times can you cross the main river in the district represented on your map ? Has it any tributaries ? Name them. In what directions do they run ?

Exercise 162.—How many railway lines are shown ? What are their lengths ? Which is the nearest to the school ? In what direction does it run ? Has it any bridges, and, if so, are they under or over the line ? Where are there tunnels, embankments, or cuttings ?

Exercise 163.—Name the places of worship, castles, ruins, and other objects of historic interest.

Exercise 164.—Where is there pasture-land ? Are there any woods ? If so, what kinds of woods are they ? Are there any marshes ?

Exercise 165.—At what intervals are the contour lines drawn ? Give the heights of six important places above sea-level. Connect the directions of the rivers with the arrangement of the contour lines.

Exercise 166.—Draw a few sections in given directions, so as to bring out (*a*) which is the steep and which the gentle slope of a ridge, (*b*) the form of some peak, (*c*) the general lie of the land.

Exercise 167.—Mark the contour lines with **waterproof**

ink according to the following or some similar scheme adopted to fill the map in question.

100— . — . — . —
200— .. — .. — .. —
300— .. . — .. . — .. . —
400— .. .. — .. .. — .. ..
500— × — × — × —
600— × . — × . — × . —

and so on.

Exercise 168.—Colour the map, according to the following scheme :—

Above 600 feet	Dark brown	—2 washes.
Between 500 and 600 feet	,, ,,	—1 wash.
,, 400 and 500 ,,	Light brown	—2 washes.
,, 300 and 400 ,,	,, ,,	—1 wash.
,, 200 and 300 ,,	Yellow	—1 wash.
,, 100 and 200 ,,	Light green	—2 washes.
Below 100 feet	,, ,,	—1 wash.

The One Inch Map.

Exercise 169.—What is (*a*) the length, (*b*) the breadth, (*c*) the area of the map ?

Exercise 170.—Give the bearings of any six important places with regard to your own town.

Exercise 171.—What are the distances of these places in a direct line from your own town ?

Exercise 172.—Choose six other places, and say what kinds of roads connect them with your own town. Consult Fig. 110 and find whereabouts on your map there are roads marked as in that figure. Draw a section of some road that goes completely across the map. Compare your section with that given in the *Contour Road Book*.

Exercise 173.—Name the chief rivers and say in what direction they flow.

Exercise 174.—Name the railways. Give their directions. Where are there tunnels, cuttings, embankments ?

Exercise 175.—Find three places where the churches are different in appearance. State what are the differences. Make rough sketches to show these differences. Give four places from which you cannot send a telegram.

Exercise 176.—Give the heights above sea-level of six different places. At what intervals are the contour lines drawn? What is the difference in height between the highest and lowest points on the map.

Exercise 177.—From one or two given points describe the view looking in several different directions.

Exercise 178.—On a piece of tracing paper map out a walk, as described by your teacher. (See some book of field path rambles for the district.) Write a description

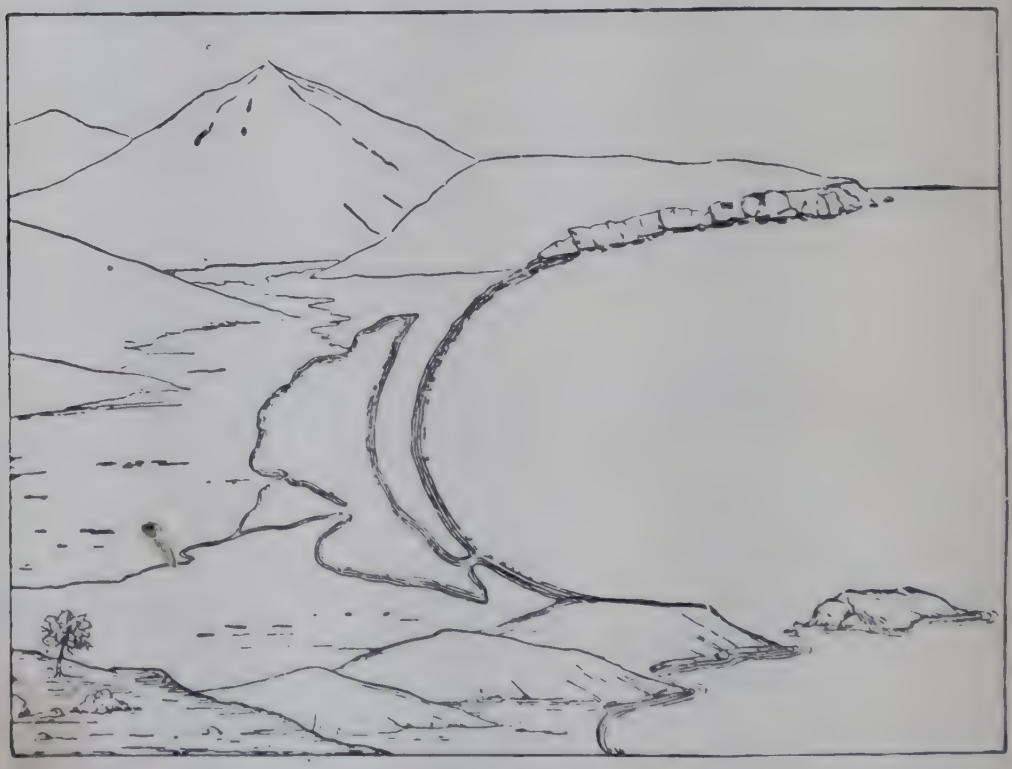

Fig. 111.

of this walk in such a way that a stranger could follow the same route without missing his way. Measure the length of the walk with a piece of thread.

Exercise 179.—Insert the contour lines in waterproof ink.

Exercise 180.—Colour the map according to the scheme in Exercise 168.

REVISION EXERCISES

1. Suppose you are going to walk to a railway station ten miles away across a stretch of open country where there are no roads or fences. You

have a compass and an ordnance map of the district, on which you can recognize the point from which you start.

Describe how you would use the map to find your way. O. P., 1907.

2. Draw a sketch showing a piece of main road which crosses a meadow (road unfenced on both sides), then passes over a stream by means of a bridge, next goes through a wood (where both sides are fenced), and on coming out of the wood passes under a railway bridge. The railway crosses the road at right angles on an embankment. N.B.—Use the conventional signs employed in the maps of the Ordnance Survey.

O. J., 1906.

3. In cycling through the village of X, I ask my way to the village of Y. I get the following directions:—"Go down the village street for about a quarter of a mile till you come to the church, which is on your left hand; then turn sharp to the right, and cross the bridge over the railway; turn to the left, and then follow the road running alongside the railway for two miles, till you come to four cross roads in a wood, just after crossing a bridge over a stream. Turn to the right, and keep to the road beside the stream for a mile; you will see the village of Y close on your right." Draw a rough sketch map which would help me to remember these directions. O. P., 1906.

4. Draw an outline sketch of the country delineated in Fig. 111. Write numbers on the map to indicate the physical features, and write the names of these physical features opposite corresponding numbers in the space below. C. J., 1906.

CHAPTER XXVII

MAPS SHOWING DISTRIBUTIONS

THE maps with which we have been working show directions, distance, area, and heights. Other maps are made to show distributions such as rainfall, temperature, and population. In these maps the main object is to represent in such a way as to catch the eye at once, facts which are stated in words or statistics. In Fig. 93 heights are shown, but not in such a way as to be obvious at a first glance. By drawing contours the relief of the country is brought out. Even contours do not always show the relief plainly: they are printed on the 1 inch ordnance maps, but the relief thus shown is somewhat obscured by the multitude of other details. By performing exercises 167 and 168 the relief is brought out more plainly.

Other facts besides those of relief may be shown in a similar way.

Exercise 181.—Fig. 112 shows the mean maximum tem-

perature for 35 years at 8 a.m. in July. Draw the isotherms for 60°, 65°, and 70° and shade or colour the map to emphasize the facts.

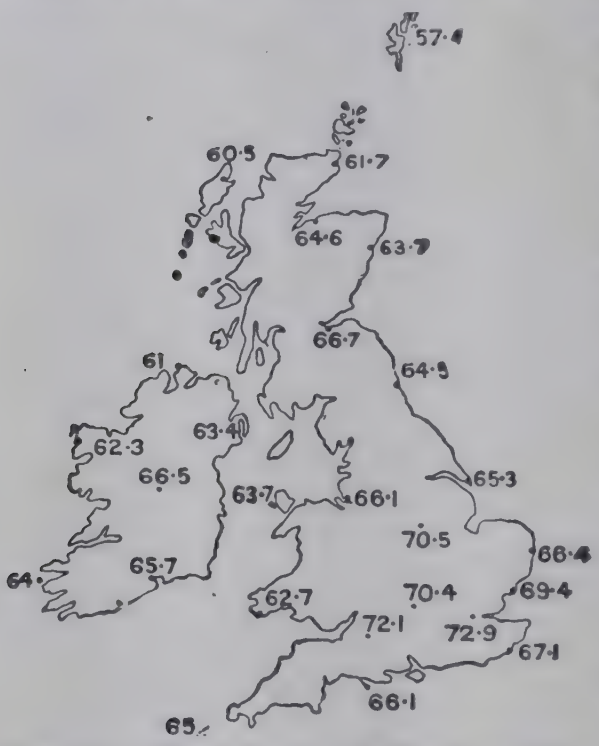

FIG. 112.—MEAN MAXIMUM TEMPERATURES FOR JULY.

In this exercise the temperatures are placed on the map for you. In the next exercise you have to plot the temperature for yourself.

Exercise 182. — The following figures show the mean minimum temperature in degrees Fahrenheit in Britain for 35 years at 8 a.m. in January. Plot these on a map. Draw the most suitable isotherms; shade or colour the map to emphasize the facts.

Shetland Islands	38·4	Oxford	33·4
Stornoway	34·3	Clacton	35·1
Wick	32·2	London	33·8
Nairn	32·2	Scilly	42·5
Aberdeen	33·2	Portland	39·6
Leith	33·7	Dungeness	35·2
Shields	33·9	Malin Head	37·7
Spurn Head	34·6	Blackross Point	38·9
Holyhead	38·4	Donaghadee	36·1
Liverpool	35·1	Valencia	40·1
Nottingham	32·3	Cork	39 4
Yarmouth	33·6	Centre of Ireland	34·1
Pembroke	39·5	Jersey	38·5
Bath	35·1		

If you use colour it is as well to use different depths of the same shade. The principle to be observed is to let the darker tint suggest the presence of the greater amount of whatever the map shows, whether it is heat, or cold, or people.

If you use different colours you suggest that different things are represented.

For line shading use either pencil or pen but not both, and take care to make the shading darker to show the greater amount. An example of good and of bad map shading is exhibited in Fig. 113. The two maps show precisely the

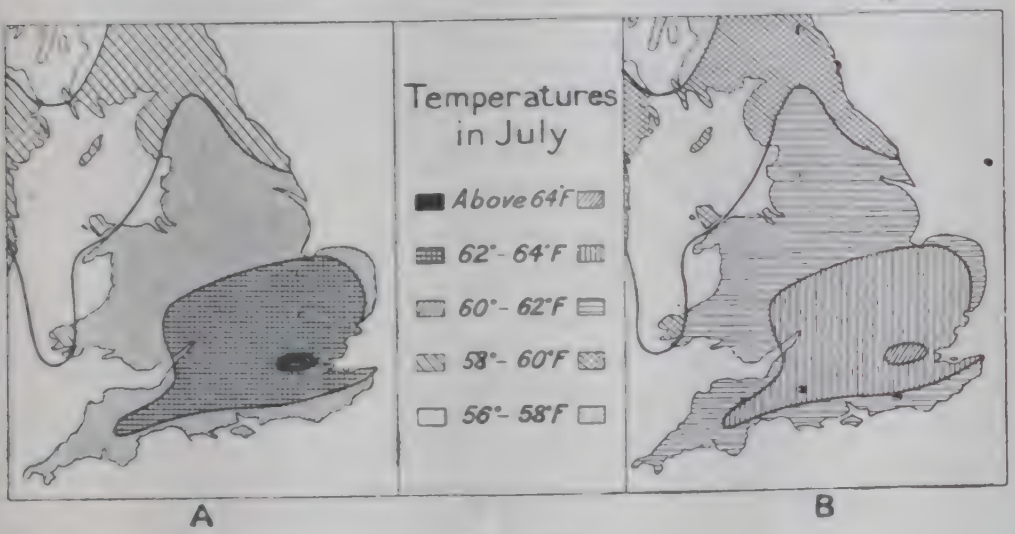

Fig. 113.

same facts, but in A the facts are more obvious than in B. As the object of such a map is to make the facts obvious A is the better map. Another kind of map is that used in the following exercise.

Exercise 183.—Draw a map of England; shade the counties, each of which is named after its county towns.

Here each county is the unit and has either to be shaded or not shaded.

Exercise 184.—Exhibit the facts given in the following figures graphically on a map. Use different shades for the following values: over 500, 250-500, 100-250, under 100, per square mile.

Population per square mile of the counties of Wales in 1921.

Anglesey	185	Flint	418
Brecknock	83	Glamorgan	1,540
Cardigan	88	Merioneth	68
Carmarthen	190	Montgomery	64
Carnarvon	229	Pembroke	149
Denbigh	233	Radnor	50

Sometimes the statistics given you are not in a form suitable for mapping directly. It is not sufficient to know the number of persons in a county, you must also know the size of the county.

Exercise 185.—Obtain statistics showing the population of each parish in your county; find also the area of each parish in square miles or acres. Then calculate the number of persons per square mile or per 1,000 acres and show the distribution of population on a map.

Exercise 186.—Find out the number of acres of wheat grown last year in each county of Britain and the area of

FIG. 114.—THE COALFIELDS OF BRITAIN.

each county. Hence construct a map showing the distribution of wheat in Britain.

When two quite different distributions require to be shown on the same map then it is convenient to use two colours, or ink and pencil.

Exercise 187.—Draw a map to show the area in Britain over 600 feet and the relation of the coalfields to this high ground.

REVISION EXERCISES.

What map network would you use to show distribution (*a*) of temperature over the world, (*b*) of population over the world.

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